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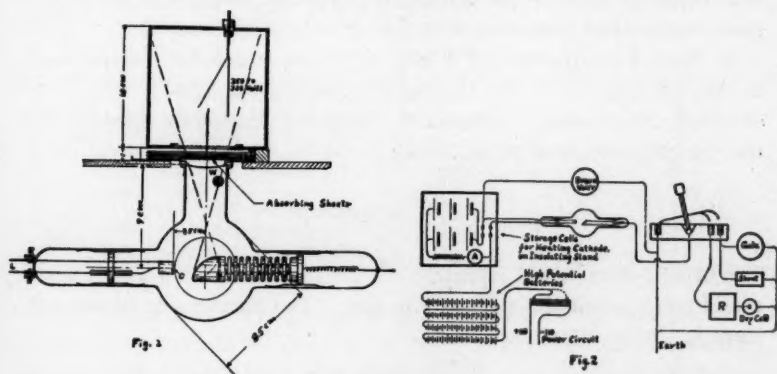
THE ABSORPTION COEFFICIENTS OF SOFT X RAYS

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The X rays studied were produced at potentials ranging from 2500 to 10,000 volts. The tube (see fig. 1) in which they were generated was provided with a hot cathode, *C*, consisting of a flat spiral of tungsten wire, similar to the cathode in a Coolidge tube. The anode was of iron, but this has no bearing on the work reported here, as the characteristic



radiation of iron did not appear in noticeable quantity. The rays escaped through an aluminum window, *W*, of 0.001823 grams per square centimeter, or of 0.000675 centimeters thickness, supported on wire gauze of 180 meshes to the inch. The rays, after passing through the sheets of absorbing material, entered the chamber of the gold leaf electroscope, by means of which their ionizing effect was measured.

The electrical connections are shown in figure 2. The cathode current from the tube was balanced by the current from the dry cell, when the resistance R was properly adjusted, by throwing the three point key to the right, and the galvanometer indicated when a balance was obtained.

The absorbing material consisted of sheets of gelatin, celluloid, aluminum foil and ordinary sheet aluminum. As the ratios between the absorption coefficients in these substances were found to be independent of the nature of the X rays, the observed absorption coefficients in gelatin and in celluloid have been reduced to equivalent absorption coefficients in aluminum, and the thickness of absorbing material through which the X rays past before the absorption coefficient was observed, has been similarly reduced to the equivalent thickness of aluminum. The ratios used for this reduction are

$$\frac{(\mu/\rho) \text{ celluloid}}{(\mu/\rho) \text{ aluminum}} = 0.171, \quad \frac{(\mu/\rho) \text{ gelatin}}{(\mu/\rho) \text{ aluminum}} = 0.162.$$

μ represents the absorption coefficient and ρ represents density, hence μ/ρ is the mass-absorption coefficient.

The results of the investigation are shown graphically in figure 3. The values of μ/ρ for the six higher potentials manifestly come to a steady value with increasing thickness of absorbing material.

In figure 4 are plotted $\log V$ and $\log \mu/\rho$ in which the values of μ/ρ are the limiting values, for the higher potentials, and the lowest values obtained, for the lower potentials. The points for the six higher potentials lie very close to a straight line, the slope of which indicates

$$\frac{\mu}{\rho} V^{2.77} = \text{constant.}$$

The other points do not represent the limiting values of μ/ρ , and hence would be expected to lie above this line. The mean value of the constant is 4.24×10^{12} ; hence

$$\frac{\mu}{\rho} = \frac{4.24 \times 10^{12}}{V^{2.77}}. \quad (1)$$

The six values of μ/ρ as given by this formula agree to within less than one per cent with the observed values.

If the 'end' radiation, which is homogeneous according to the absorption test, has a definite frequency given by the quantum theory relationship

$$Ve = hv, \tag{2}$$

then

$$\frac{\mu}{\rho} = 19.4\lambda^{2.77}. \tag{3}$$

The mass per square centimeter of aluminum, ρd , which was found necessary to render the X rays approximately homogeneous, is given, as nearly as could be observed, by

$$\rho d = 10^{-12} \times V^{2.77}. \tag{4}$$

It has been known for some time that an equation of the form of (3) would represent roughly the relationship between absorption coefficients and wave lengths, but the exponent has been estimated by

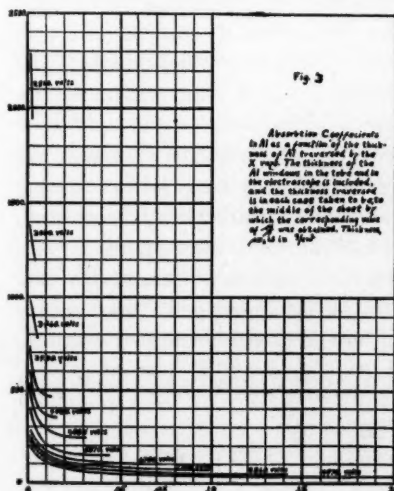


Fig. 3
Absorption Coefficients in Al as a function of the thickness of Al traversed by the X ray. The thickness of the Al windows in the tube and in the electroscopie is included, and the thickness traversed in each case taken to be the middle of the sheet by which the corresponding unit of μ/ρ was obtained. This unit, μ/ρ , is in cm^{-1} .

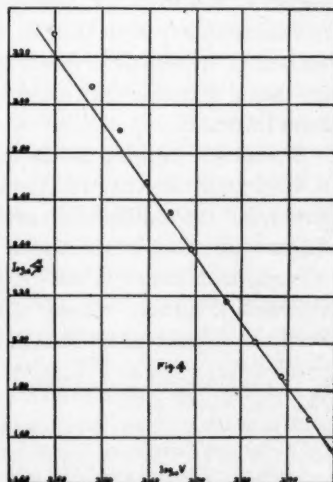


Fig. 4

Bragg,¹ who is perhaps the foremost observer, at from 2.5 to 3.0, whereas these results indicate it to be 2.77 ± 0.03 . Bragg's estimate is based on the absorption coefficients of monochromatic rays obtained by the use of the X ray spectrometer. It has also been known² that X rays produced at steady potentials become homogeneous after passage through a sufficient thickness of absorbing material. However, no formula such as (4) has been given by which to estimate the necessary thickness. Data similar to those on which equation (1) is based have been used by Duane and Hunt³ and by Rutherford, Barnes and Richardson⁴ to calculate wave lengths by means of relationships similar to (3),

although the constants in this equation were not accurately known, and thus to test the quantum relationship (2). The results of Hull⁵ indicate clearly that the quantum relationship (2) holds for the maximum or limiting frequency of the X rays produced at high potentials, but although the range of potentials used by Rutherford (13,200 to 175,000 volts) was sufficient for the accurate determination of the constants of (1) or (3), they cannot be determined from his results, either because such relationships do not hold for very high potentials, or because the X rays had not passed through a sufficient thickness of absorbing material to give the limiting values of the absorption coefficients. The X rays produced at the potentials used by Rutherford and by Duane are of such penetrating power that no special window such as *W*, figure 1, was necessary. X rays produced at the potentials used in this investigation (2,500 to 10,000 volts) are of such low penetrating power that it was necessary to make the window *W* as thin as could be made to withstand atmospheric pressure, and to use the thinnest sheets of absorbing material that could be obtained, and still have them of uniform thickness.

Summary.—A relationship such as (3) has been known for some time to hold approximately for X rays of the ordinary range of penetrating power, but the constants have not previously been accurately determined. These results indicate that such a relationship holds for very much softer X rays, and values of the constants have been determined with considerable accuracy. These values are in agreement with those which hold for the higher potentials, as nearly as the latter have been determined.

¹W. H. Bragg and W. L. Bragg, *X Rays and Crystal Structure*, p. 180. W. H. Bragg *Phil. Mag.*, March, 1915.

²Wm. R. Ham, *Physic. Rev.*, January, 1910.

³Duane and Hunt, *Proc. Amer. Phys. Soc.*, *Physic. Rev.*, August, 1915.

⁴Rutherford, Barnes and Richardson, *Phil. Mag.*, September, 1915.

⁵Albert W. Hull, *Proc. Amer. Phys. Soc.*, *Physic. Rev.*, January, 1916.

FURTHER EVIDENCE AS TO THE RELATION BETWEEN CROWN GALL AND CANCER

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1. *Fundamental concepts.*—It is my belief that a diligent study of tumors in plants will help to solve the cancer problem. Expressed in other words, my text is this: Cancer occurs in many kinds of plants in which it passes through an essentially parallel course of development

to that of cancer in man and animals, some allowance, of course, being made for differences in the structure and development of plants. My concept is this, that fundamentally plants and animals are alike, that physical and chemical laws apply equally, that is uniformly, to all living things, and hence that discoveries relative to the fundamental cell-mechanics of animals apply equally to plants, and vice versa.¹ If cancer occurs in plants and is due to a parasite, as I maintain, then cancer in man must also be due to a parasite, and since I show that several kinds of plant cancers are due to the same organism, the differences being due solely to unlike tissue reactions, we may anticipate the same thing to be true in man, and search for one parasite rather than many.

2. *Human and animal tumors for which no cause has been discovered.*— These tumors fall readily into two groups which intergrade more or less. These are (a) encapsuled benign tumors, and (b) free-growing malignant tumors or cancers. I will here consider only the malignant tumors. There are several types of these; the simplest and the commonest being proliferations (1) of the connective tissues, resulting in fleshy tumors known as *sarcomas*, and (2) of the various kinds of epithelium, resulting in eroding tumors known as *carcinomas*. In addition to tumors of the brain and nervous system, which are sometimes malignant but which may here be left out of account, there are (3) very curious tumors containing mixed tissue elements of two germ layers (connective tissues, cartilage, striped and plain muscle-fibres, glandular tissue, etc.) some of which are benign while others are extremely malignant, and finally, (4) embryonal teratomas which, in addition to the cancerous element, contain numerous foetal fragments, derived from all three of the primitive germ layers, often a great variety of tissue-fragments, variously fused and jumbled, but all embryonic and never coming to maturity.

The leading characteristics of these cancerous tumors are (1) Unlimited cell proliferation emancipated from bodily control; (2) Appearance of destructive secondary tumors, often in vital organs, which tumors are derived from the primary tumor either by development from dislodged creeping and floating tumor cells, or by uninterrupted growth from a chain of tumor cells originating in the primary tumor. These secondary tumors wherever they are developed repeat more or less closely the structure of the parent tumor. Add, to these manifestations, (3) a destructive action on surrounding tissues, which are crushed, absorbed or poisoned, and we have in brief the main phenomena of can-

cerous growth. The other phenomena are subsidiary and may be left out of account in this brief abstract.

3. *Earlier discoveries in plants.*—In 1907 the author and his colleagues (Townsend and Brown) proved that a common hyperplasia of various cultivated plants which had been for many years under observation in this country and in Europe and for which various causes had been inconclusively assigned (frosts, physiological disturbances, mites, myxomycetes, etc.) was really due to a polar flagellate schizomycete, named by us *Bacterium tumefaciens*. This was first cultivated from tumors on the Paris daisy in 1906, but afterwards it was obtained from various other plants, in several distinct strains (daisy strain, hop strain, etc.) and shown to be cross-inoculable on a variety of plants with resultant tumors in which no bacterial cavities or bacterial occupation of cells, vessels, or intercellular spaces could be seen in fresh material or demonstrated in serial sections by stains, and yet from which the causal organism was readily cultivable in small numbers by the common methods of the bacteriologist.

4. *Further discoveries.*—In 1911 I discovered in inoculated Paris daisies a parenchymatous tumor-strand connecting the primary stem tumors with deep-seated secondary tumors which had developed in the leaves some weeks after the stem inoculations. I also showed these secondary leaf-tumors to be possessed of stem structure, i.e., to have the structure of the primary tumor, thus following the law of cancer in man and animals. These discoveries were fully illustrated and described at that time in United States Department of Agriculture bulletins² and elsewhere. From the origin, structure and general appearance of these tumors I likened them to sarcomata.

5. *Other resemblances of crown gall to cancer in man and animals.*—Without entering into details which may be found elsewhere a few other resemblances are here summarized: (1) No parasite visible; (2) Embryonic character and rapid multiplication of the proliferating cells; (3) Loss of polarity in the proliferating tissues; (4) Invasive surface growth of the tumor and absence of a capsule; (5) Non-granulomatous development of secondary tumors; (6) Growth in autonomous species from grafts; (7) Presence of degenerative changes in the proliferating cells as shown by behavior toward stains, by lobed and cleft nuclei, polynuclear cells, etc.; (8) Destruction of surrounding tissues; (9) Defective vascularization and early central necrosis with invasion of the open wounds by secondary parasites and by saprophytes; (10) Frequent return after excision; (11) Presence of atrophy and cachexia.

6. *Possibility of the existence of carcinomas and of mixed tumors in plants.*—Slides were shown suggesting that it is experimentally possible to induce the proliferation of glandular tissue and the epidermis (skin) of plants by bacterial inoculations, but so far no metastases have been obtained. This whole subject, however, is yet in its infancy and further reports will be made from time to time as results are obtained.

7. *Production of embryonal teratomata.*—Last winter I discovered that when growing plants are inoculated in the vicinity of dormant buds a new type of tumor is produced. This tumor bears on its surface diminutive abortive shoots (vegetative or floral), and in its interior, along with the cancer cells, numerous fragments of embryonic tissues, variously fused and oriented, often upside down and curiously jumbled. These tumors have never been seen by the writer in nature or at least if seen not recognized as crown gall tumors, but undoubtedly we shall now find them.³ These tumors have all been produced with *Bacterium tumefaciens* plated from an ordinary sarcoma-like tumor of the hop received from the Pacific Coast 8 years ago. The plants chiefly experimented on have been Pelargonium, Nicotiana, Lycopersicum, Citrus, and Ricinus. All of these and some others (Mangifera, Allamanda, etc.) have yielded teratoid tumors from inoculations in leaf axils.

The inoculated tobacco also developed secondary teratoid tumors at a distance from the primary tumor in both stems and leaves, i.e., tumors bearing numerous diminutive and abortive shoots, which at longest have lived but a few months. In other words, like the secondary tumors on the Paris daisy they have repeated the structure of the parent tumor but this time that which is repeated is not a simple sarcoma developed out of fundamental tissues but a complex tumor comparable to the embryonal teratomata or atypical teratoids occurring in man. Many attempts have been made in recent years to produce such tumors in animals but hitherto all experimenters have failed. Monsters, it is true, have been produced repeatedly by fragmenting eggs, and in other ways, but always they have been *typical teratoids*, never cancers.

However, the most striking result I have obtained is yet to be told. All the embryomas previously mentioned were obtained by making my bacterial inoculations in the vicinity of dormant buds (totipotent anlage) which were then apparently torn by the rapid growth of the tumor, the fragments being variously distributed in the tumor and there stimulated to develop, the result being embryonic growths of extremely variable size but all referable to the original disturbed shoot-anlage. If, however, inoculations are made in regions not known hitherto to

contain totipotent cells, the same results can be obtained, e.g., I have obtained on the tobacco a shoot-bearing tumor from the middle of an internode, and numerous such tumors from various parts of leaves, twenty-seven on a single plant, seven on a single leaf, and too many it would seem to be explained on Cohnheim's theory,⁴ i.e., as growths due to the development of embryonic 'cell rests,' which are conceived to be fragments displaced from the embryo in early stages of its growth and enclosed in other tissues where they remain dormant until a cancer stimulus sets them growing.

8. *Bearing of these discoveries on the cancer problem.*—It has been pointed out repeatedly that embryomas are the crux of the whole cancer problem. Hitherto they have remained unexplained. Now I have succeeded in bringing them into correlation with the simpler forms of cancer by showing that they also are specific tissue responses to the stimulus of a specific schizomycete. If one set of plant tissues is inoculated sarcoma develops; if another set, carcinoma (?); if a third set (and this time it must be a complex anlage containing totipotent or nearly totipotent cells), an embryoma develops. To a biologist, therefore, the conclusion is almost irresistible that human cancer must be due to a parasite, and that one parasite may well be the cause of the most diverse forms, as we have seen to be the case in plants. Those who consider plants and animals so different that no conclusion can be drawn from the one to the other will see no interrelation, but I am hoping the recorded facts will make a strong appeal to those who know something about cell metabolism and the similar response of living plants and animals to a great variety of stimuli.

¹See *J. Cancer Res.*, 1, No. 2, April, 1916, and *Science*, N. S., 43, 871, where I have elaborated this idea and also other ideas only touched upon here.

²*Bureau of Plant Industry, Bulletins* No. 213 and No. 255.

³As this goes to press I have had confirmation of this belief, having received from a florist in Massachusetts a crown gall of the rose showing abortive shoots growing out of stem tumor.

⁴For illustrations of teratomas produced in tobacco leaves by direct bacterial inoculation consult *J. Agric. Res.*, April 24, 1916, Plate 23.

LOCOMOTION OF SEA-ANEMONES

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Although sea-anemones belong to a group of animals characterised by radial symmetry, they have long been known to exhibit a bilateral arrangement in their mesenteries and adjacent parts. Most bilateral animals move in definite relations to their axis of symmetry. Is this true of sea-anemones?

Single specimens of *Actinia* or of *Sagartia* will creep now in the direction of their planes of symmetry, now at any angle to those planes and thus demonstrate the entire independence of the direction of locomotion and the axis of symmetry. This is especially clearly seen in *Sagartia* which will creep away from a source of light irrespective of the relation momentarily called forth between the direction of locomotion and the animal's structural axis. Locomotion in sea-anemones is therefore a radial operation performed by the radial pedal disc and not necessarily associated with the more or less bilateral oral disc.

Locomotion is accomplished by a wave-like movement that progresses over the pedal disc in the direction of locomotion. In a specimen of *Sagartia* with a pedal disc of about 4 mm. diameter, the locomotor wave coursed over the disc in an average time of 1.65 minutes and with each wave the animal progressed on the average 1.2 mm. In a large sea-anemone, *Condylactis*, with a pedal disc 130 by 80 mm. the passage of a locomotor wave required on the average three minutes and the animal progressed for each wave on the average 11.4 mm.

In the locomotion of sea-anemones each part of the pedal disc is successively raised from the substratum, moved forward, and put down. The attachment to the substratum is due chiefly to adhesion heightened by the secretion of a thick slime rather than to a sucker-like action of the pedal disc. The mechanism of locomotion consists of the circular muscle of the pedal disc, the basilar muscles, and the longitudinal muscles of the mesenteries all of which act on the fluid-filled spaces in the pedal region. The pressure thus generated is not above 6 cm. of water.

Specimens of *Sagartia* from which the oral disc has been cut off will creep in an essentially normal manner, for instance, away from a source of light. Hence the pedal portion of a sea-anemone, like its tentacles,

must contain a neuromuscular mechanism sufficient for the activity of that part of its body.

The extended publication will appear in the *Journal of Experimental Zoölogy*.

THE BEHAVIOR OF SEA-ANEMONES

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The older students of sea-anemones, such as Gosse and von Lendenfeld, believed that these animals were endowed with mental traits not unlike those of man. Later workers, such as Loeb, Jordan, and others, regard these forms as finely adjusted machines devoid of psychic attributes. To discover something of the nervous nature of these animals two forms of their behavior were studied in detail, the appropriation of food, and general retraction. The work was carried out for the most part on *Metridium* and *Sagartia*.

In the appropriation of food, the parts chiefly concerned are the five following: the tentacular gland cells whereby the tentacles are rendered adhesive for food, the tentacular muscles by which the tentacles are pointed toward the mouth, the tentacular cilia by which the food is delivered from the tip of the tentacle to the mouth, the transverse mesenteric muscles whose action opens the mouth, and the oral cilia (lips and oesophagus) whose reversal in the presence of food carries this material into the digestive cavity of the sea-anemone. Of these five parts the mucous cells, the tentacular cilia, and the transverse mesenteric muscles are so uniform in their action that they need no further consideration. The oral cilia and the tentacular muscles on the other hand are much more open to variation and hence may serve to indicate to some extent the condition of the animal as a whole.

The oral cilia after having reversed their effective stroke in the presence of food a number of times, eventually cease to show this change, a condition supposed to be due to altered metabolism as a result of feeding. But this same cessation occurs when the oral membranes are cut from the animal and worked with separately. It is strictly local in its appearance and probably a pure fatigue effect.

The feeding movements of the tentacles, though also modified by fatigue, have been supposed to show changes of a more significant kind. If the tentacles on one side of the animal are much exercised, those of

the other side decrease in responsiveness. This change has also been supposed to be due to changed metabolism, but, since it appears quickly and before a general metabolic change can have occurred, it is probably that this too is the result of fatigue in that the food juices from the cavity of the tentacles transfuse the walls of these organs and thus reduce the sensitiveness of their exterior. Thus none of the elements in the feeding responses of sea-anemones imply that these animals are organisms that respond as firmly united wholes.

Retraction, whereby the more delicate parts of the sea-anemone are drawn in and covered, is the commonest protective act of this animal. Expansion is the reverse of retraction and puts the animal in form for full activity. Vigorous mechanical stimulation, most chemical stimuli, strong light, and high temperature induce retraction. The presence of food in the adjacent water, and water currents induce expansion. Oxygen as such seems to have little effect on these reactions.

Sagartia retracts when left dry by the tide and expands when it is again covered by the returning water. *Metridium* retracts in bright daylight and expands at night. The tidal rhythm of *Sagartia* and the nycthemeral rhythm of *Metridium* are not retained after the rhythmic stimulus is removed as has been claimed for European species by Bohn. There is also no evidence of an anticipatory reaction to the tides as maintained by Piéron. The retraction and expansion of sea-anemones, therefore, give no support to the view that these animals act under highly specialized nervous states.

The form of response which more than any other involves a sea-anemone as a whole is creeping. But even this form of activity can be accomplished by the pedal half of the animal. To repeated stimuli sea-anemones quickly adjust themselves rather by a process of adaptation than by one of exhaustion. Yet they have been found to show no evidence of associative capacity. They are animals whose momentary conditions are dependent upon the combined stimuli of their immediate surroundings rather than forms that are greatly influenced by their past history. And in consequence of this their unity is not of a pronounced type. They are more in the nature of a sum of parts than they are organic units such as we are familiar with among most of the higher animals.

The extended paper will be published in the *Journal of Experimental Zoölogy*.

A CONTRIBUTION TO THE PETROGRAPHY OF JAPAN

By J. P. Iddings and E. W. Morley

BRINKLOW, MARYLAND, AND WEST HARTFORD, CONNECTICUT

Read before the Academy, April 17, 1916. Received, June 17, 1916

It has been known for many years that the volcanic lavas of the Japanese islands are chiefly pyroxene-andesites, and that other lavas are more siliceous and some less so, but the actual chemical composition of most of them has long remained unknown, though chemical analyses of a few varieties have been published. This was the case to within a few years, when some of the principal volcanoes were visited by one of us in order to study various forms of craters of a few of the many active volcanoes of this region, and to collect material for chemical and microscopical study. Since that time a number of excellent chemical analyses of igneous rocks have been made in the laboratory of the Imperial Geological Survey of Japan, some of which have been published in volume 2 of *Igneous Rock* by J. P. Iddings.

The accompanying seventeen analyses, by E. W. Morley, furnish new chemical data relating to lavas of several of the most prominent Japanese volcanoes, and form a series from the basalts, or basaltic andesites, of Fuji yama and Aso to dacites and rhyolites of less well-known localities.

The habit of the pyroxene-andesites is much the same in all the varieties collected, except that some are compact rocks, others vesicular. They have abundant small phenocrysts, that is, they are semipatic and seriate minophyric. The most abundant phenocrysts are strongly calcic feldspars. Pyroxenes are inconspicuous and are in large part hypersthene, the relative amounts of augite and hypersthene varying considerably. Olivine occurs as phenocrysts in few of the rocks analyzed, and quartz phenocrysts in a few. Magnetite is abundant in most of the andesites, chiefly as microscopic constituents of the groundmass together with microlites of feldspar and pyroxene. It also forms small phenocrysts.

While the lavas at each volcano vary somewhat in composition, the variation is within narrow limits so far as observed. The material analyzed represents characteristic rock from each locality, but not all that occurs there. Analysis 1 is of the rock from the Hoyei crater on the east slope of Fuji yama. The rock is basalt with andesitic habit, and contains abundant olivine and is the lowest in silica of the rocks analyzed. Nevertheless, the calculated norm contains a small amount

of quartz with considerable normative hypersthene. The normative feldspar is strongly calcic.

Recent lava from the north rim of the central crater of the volcano Aso, is pyroxene-andesite, anal. 2, with nearly the same chemical composition as the basalt from Fuji yama, and with slightly more normative quartz, but no modal olivine, so far as observed. The normative feldspar is less calcic and there is less of the femic components. The chemical resemblance between the two rocks is well shown by the symbols and magmatic names.

The lava of Niokiba crater, Nazu volcano, which was erupted in 1881, anal. 3, is typical bandaite, that is, it is a pyroxene-andesite with laboradorite feldspars and a notable amount of normative quartz, some of which appears as quartz phenocrysts. The next six rocks, anal. 4 to 9, are pyroxene-andesites, which are transitional bandaïtes, since the normative feldspars are andesine-laboradorite. The lavas occur at widely scattered volcanoes, Zao San, Asama yama and Azuma yama on the main island, Hondo; Ohachi, and Shimasaki, a quarry near Kumamoto, on Kyushu; and Komagatake, on Hokkaido.

The lava erupted from Tarumai, Hokkaido, in 1909, anal. 10, is chemically similar to the preceding, but the feldspars are slightly less calcic. It is a transitional variety of pyroxene-andesite related to bandaïte. The andesite from the rim of the central crater of Iwakisan, in northern Hondo, anal. 11, is closely similar to bandaïte, with somewhat less pyroxene. The rock from the southern summit of Sakurajima, Kyushu, anal. 12, which was collected in 1910, before the last great eruption of this volcano, is a glassy pyroxene-andesite, having the chemical composition of an andesine-dacite, or shastaite. The hornblende-mica-andesite of Mae yama, near Shimabara, anal. 13, and the spherulitic dacite from Kosaka, Hondo, anal. 14, are chemically similar, though modally quite unlike. They may be classed as shastaites, because of the character of their normative feldspars. The glassy dacite, anal. 15, from near the Shinyu Inn at the west base of Aso, Kyushu, is a variety of ungaite, judging by the norm. The normative plagioclase is oligoclase, with which is subordinate normative orthoclase. It may be classed as an oligoclase-dacite transitional to dellénite.

Analysis 16 is of a garnet-bearing rhyolitic obsidian, from Hiwashima, and analysis 17 is of a spherulitic rhyolitic obsidian said to occur on the sea coast north of Kagoshima and Sakarajima. The seventeen analyses show that there is a strong chemical likeness among the rocks collected, which is well brought out by the norms and magmatic symbols.

TABLE OF CHEMICAL ANALYSES AND NORMS OF JAPANESE LAVAS

	1	2	3	4	5	6	7	8
SiO ₂	50.61	53.38	58.93	57.04	57.75	59.27	59.79	60.95
Al ₂ O ₃	17.84	18.15	16.56	15.78	17.50	16.66	17.41	16.30
Fe ₂ O ₃	2.97	2.27	2.82	2.36	3.45	1.56	1.84	2.47
FeO.....	7.12	6.21	4.36	5.37	3.54	4.79	4.27	4.05
MgO.....	5.99	3.60	3.81	4.44	3.87	3.97	3.19	3.27
CaO.....	10.14	9.60	7.84	7.54	7.45	7.77	7.34	7.29
Na ₂ O.....	2.48	2.89	2.34	2.74	2.83	2.92	2.71	2.50
K ₂ O.....	0.74	1.75	1.00	1.31	1.33	1.03	1.85	1.68
H ₂ O-.....	0.00	0.00	0.25	0.39	0.17	0.00	0.00	0.12
H ₂ O+.....	0.39	0.14	0.71	1.32	0.44	0.16	0.11	0.32
TiO ₂	0.66	0.86	0.59	0.79	0.67	0.81	0.63	0.60
P ₂ O ₅	0.34	0.29	0.15	0.19	0.26	0.55	0.33	0.07
MnO.....	0.80	0.43	0.44	0.44	0.53	0.35	0.15	0.19
ZrO ₂	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.00
CO ₂	0.00	0.01	0.03	0.00	0.01	0.01	0.00	0.00
Cl.....	0.08	0.05	0.07	0.12	0.06	0.06	0.14	0.09
F.....	0.04	0.10	0.08	0.08	0.03	0.02	0.07	0.02
S.....	0.03	0.02	0.02	0.05	0.08	0.06	0.08	0.05
Cr ₂ O ₃	0.02	0.00	0.01	0.01	0.01	0.00	0.00	0.00
BaO.....	0.03	0.04	0.02	0.08	0.04	0.03	0.08	0.04
SrO.....	0.02	0.03	0.00	0.01	0.02	0.04	0.04	0.02
	100.30	99.82	100.02	100.08	100.05	100.07	100.04	100.03

Norms

q.....	1.38	3.66	18.42	12.42	14.52	15.42	15.60	19.32
or.....	4.45	10.56	5.56	7.78	7.78	6.12	11.12	10.01
ab.....	20.96	24.63	19.91	23.06	24.10	24.63	23.06	20.96
an.....	35.31	31.14	31.97	26.97	31.14	29.47	29.75	28.36
c.....								
di.....	10.63	11.77	4.73	7.94	3.13	4.54	3.86	6.31
hy.....	20.64	12.10	12.62	14.61	11.64	14.54	11.65	9.37
mt.....	4.41	3.25	4.18	3.48	5.10	2.32	2.55	3.71
hm.....								
il.....	1.37	1.67	1.22	1.52	1.22	1.52	1.22	1.22
ap.....	0.67	0.67	0.34	0.34	0.67	1.34	0.67	
etc.....	0.61	0.38	1.16	2.08	0.86	0.38	0.53	0.66
	100.43	99.83	100.11	100.20	100.16	100.28	100.01	99.92

1. Basalt, hessose-auvergnose, (II) III. 5. 4. 4'. Fuji yama.
2. Pyroxene-andesite, andose-hessose, II. 5. (3) 4. 4. Aso, central crater.
3. Pyroxene-andesite, bandaite, bandose, II. 4. 4. 4. Nazu, lava 1881.
4. Pyroxene-andesite, tonalose-bandose, II. 4'. (3) 4. 4. Zao San.
5. Pyroxene-andesite, tonalose-bandose, II. 4. (3) 4. 4. Shimasaki, Kumamoto
6. Pyroxene-andesite, tonalose-bandose, II. 4. (3) 4. 4. Asama yama, erupt. 1909.
7. Pyroxene-andesite, tonalose-bandose, II. 4. (3) 4. 4. Ohachi, Takachiho,
8. Pyroxene-andesite, tonalose-bandose, II. 4. (3) 4. 4. Azuma yama, lava 1893.
9. Pyroxene-andesite, tonalose-bandose, II. 4. (3) 4. 4'. Komagatake, Hokkaido.

TABLE OF CHEMICAL ANALYSES AND NORMS OF JAPANESE LAVAS

9	10	11	12	13	14	15	16	17
59.76	58.63	61.89	64.98	65.89	70.43	70.72	73.64	76.64
17.69	17.32	17.89	15.89	16.02	15.55	14.79	14.35	12.08
5.13	4.53	3.73	1.89	1.97	1.24	0.75	0.40	0.73
2.16	3.12	1.66	4.22	2.16	1.19	1.35	0.99	0.66
2.65	2.98	2.09	1.83	2.20	0.78	0.94	0.21	0.24
6.97	7.40	6.48	3.22	3.93	3.53	1.50	0.63	1.28
3.15	3.50	3.39	3.31	3.67	4.08	4.19	4.33	3.54
0.93	1.20	1.19	1.87	2.67	1.41	4.25	3.79	3.11
0.09	0.01	0.18	0.04	0.00	0.42	0.02	0.04	0.00
0.24	0.12	0.27	0.62	0.31	0.71	0.57	0.47	0.99
0.56	0.54	0.50	0.75	0.51	0.13	0.34	0.03	0.25
0.23	0.12	0.01	0.26	0.26	0.12	0.12	0.23	0.12
0.44	0.13	0.09	0.70	0.42	0.15	0.23	0.18	0.32
0.00	0.00	n. d.	0.02	0.00	0.00	0.00	0.00	0.01
0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.01
0.10	0.06	0.14	0.12	0.06	0.05	0.06	0.18	0.19
0.03	0.06	0.03	0.05	0.05	0.06	0.05	0.03	0.05
0.03	0.03	0.09	0.07	0.02	0.06	0.02	0.14	0.06
0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00
0.05	0.06	0.04	0.10	0.06	0.04	0.04	0.16	0.06
0.04	0.03	0.00	0.00	0.00	0.04	0.06	0.00	0.00
100.27	99.85	99.71	99.95	100.21	100.01	100.03	99.82	100.34

Norms

19.86	14.82	20.94	27.18	22.32	32.46	24.60	32.34	41.10
5.56	7.23	7.23	11.12	16.12	8.34	25.58	22.24	18.35
26.72	29.34	28.82	27.77	30.92	34.58	35.63	36.68	29.87
31.41	28.08	29.75	13.90	17.51	16.68	6.67	1.39	5.56
			3.37	0.61	1.22	0.71	2.65	0.92
1.51	6.15	1.73						
5.90	6.06	4.40	10.67	7.74	3.09	4.12	2.22	1.39
6.73	6.50	4.18	2.78	3.02	1.86	1.16	0.70	0.93
0.48		0.80						
1.06	0.91	0.91	1.37	0.91	0.30	0.64		0.46
0.34	0.34		0.67	0.67	0.34	0.34	0.67	0.34
0.58	0.37	0.77	1.02	0.50	1.38	0.85	1.02	1.36
100.15	99.80	99.53	99.85	100.32	100.25	100.30	99.91	100.18

10. Pyroxene-andesite, bandose-tonalose, II.4'.3'.4. Tarumai, lava 1909.

11. Pyroxene-andesite, bandose-yellowstonose, I (II).4.(3)4.4. Iwakisan.

12. Pyroxene-andesite, shastaite, dacose-tonalose, 'II.4'.3'.4. Sakurajima.

13. Hornblende-mica-andesite, tonalose-yellowstonose, I (II).4'.3'.4. Mae yama, Shimabara.

14. Spherulitic dacite,-yellowstonose, I.(3)4'.3'.4'. Kosaka.

15. Glassy dacite, lassenose-toscanose, I'.4'.2'.3(4). Aso, west base, above Shinyu Inn.

16. Rhyolitic obsidian, liparose-kallarudose, I.(3)4.1.(3)4. Hiwashima.

17. Spherulitic rhyolite, tehामose-alsbachose, I.3'.2'.(3)4. Coast north of Kagoshima.

IS THERE A TEMPERATURE COEFFICIENT FOR THE DURATION OF LIFE?

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In 1908 one of us raised the question whether there is a definite temperature coefficient for the duration of life.¹ This might be expected if the duration of life depended upon the presence of certain substances which were used up during life; or if the duration of life were limited by the cumulative injurious effects of certain products of metabolism. Thus, Metchnikoff² has mentioned the possibility that the duration of the life of the moth of the silk worm is limited by the retention of certain poisonous substances contained in the urine. The rapidity of consumption of the necessary substance in the case of the first or the velocity of the accumulation or action of injurious substances in the case of the second hypothesis should increase with the temperature according to a certain law.

It seems that there exists for each species a pretty definite duration of life in spite of the fact that injuries of various types may shorten the life of the individual. The annual plants, the sequoia of the sierras, the human, the insects, have their characteristic duration of life. On the other hand, it was shown by Leo Loeb that the cancer cell is immortal and he pointed out that this might be the case for all cells. Then the problem arises, what is the cause of the fact that each species has a limited duration of life the magnitude of which is characteristic for the species? If the answer to this question is given by one of the two hypotheses mentioned in the first paragraph of this paper, it may be expected that there should be found a temperature coefficient for the duration of life of the order of magnitude of that of chemical reactions. A search for such a temperature coefficient can only be attempted on a form with a naturally short duration of life. We have selected for this purpose the fruit fly *Drosophila*.

Newly hatched flies were put into large Erlenmeyer flasks kept in thermostats 34°, 31°, 28°, 24°, 14°, and 9°. Each flask contained on the average about 100 flies. The number of dead were counted each day and the surviving flies were put into fresh flasks every two days. Each determination of the duration of life was based upon at least two and often as many as twelve cultures of about 100 flies each. The values for the mean length of life of the flies in the separate cultures, at a given

temperature, was averaged and this value taken as the average duration of life for that temperature.

Three series of experiments were made. In one the flies were provided only with water, in the second with a 1% cane sugar solution, and in the third with fermented banana. In the third series the results were less regular than in the first two series, probably on account of differences in the nature of microorganisms present in the food. We intend to repeat these experiments with sterile cultures of flies which we are now raising, and will report on these experiments in a later publication.

The following table gives the average duration of life for different temperatures.

TEMPERATURE	DURATION OF LIFE IN DAYS	
	With H ₂ O	With 1 % cane sugar
°C.		
34	2.1	6.2
28	2.4	7.2
24	2.4	9.4
19	4.1	12.3
14	8.3	
9	11.9	

If we consider the figures for temperatures between 28° and 9° for the cultures in water and in sugar we find that there exists a temperature coefficient for the duration of life of about the order of magnitude of that of chemical reactions, namely, of about 2 for a difference of 10°C. We find also that the coefficient is greater for the lower range of temperatures. The same temperature coefficient was also found by previous authors for the time required for the development of the eggs of animals and incidentally also by us for the larval period of these flies; with this difference only, that in the latter case the coefficient is more regular.

These experiments therefore show that the duration of life in the cases examined has a temperature coefficient of that order of magnitude which is characteristic for life phenomena and for chemical reactions in general.

¹Loeb, J., *Arch. ges. Physiol.*, 124, 411 (1908).

²Metchnikoff, E., *Ann. Inst. Pasteur*, 29, 477, (1915).

ON THE SUGGESTED MUTUAL REPULSION OF FRAUNHOFER LINES

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The correct interpretation of the results given by the spectroscope is so fundamental to progress in present day astronomy that every suggestion offering new points of view and avenues of approach to the problems furnished by the powerful instruments in commission deserves consideration. The spectrographs now used upon the sun yield spectra of such a scale and dispersion that minute changes in spectrum lines can be studied that were beyond the reach of the older instruments.

Changes in the relative position of spectrum lines are the phenomena most often under consideration. All astrophysicists recognize two conditions that produce displacements of the Fraunhofer lines, motion in the line of sight and differences in pressure, both capable of precise determination. Two others have been suggested, the gravitational effect of Einstein¹ and the anomalous dispersion hypothesis of Julius.² The former influence would displace all lines to a calculable amount and would, if found, add no serious difficulties to the solar problem. The effects of anomalous dispersion, however, would introduce an indeterminate factor into the spectroscopic problem. It becomes then a matter of prime importance to determine whether the relative positions of the Fraunhofer lines are measurably affected by this cause.

An accepted deduction from the theory is a mutual influence between neighboring lines, a quasi repulsion increasing with the proximity of the adjacent lines. The violet and red components of a close pair must then be displaced to the violet and red, respectively, in comparison with the displacement of the isolated lines of the same class. Displacements between the solar and arc lines give a direct and definite means of testing the question.

Iron, from its abundance of lines and the searching investigations given to them, furnishes the most reliable data. The wave lengths of the iron lines belonging to groups *a*, *b* and *c4* of the Mount Wilson classification are independent of arc conditions.³ These lines therefore are capable of giving results of the highest possible precision. The mean sun-arc displacement for 213 lines of these groups is +0.0039 A. Those who assign an important rôle to anomalous dispersion in the solar atmosphere assume that solar lines within 0.5 A from each other are subject to mutual repulsion. The mean displacement for 30 lines with

companions at an average distance of 0.314 A to the red is +0.0042A; for 59 lines with companions at an average distance of 0.270 A to the violet it is +0.0040 A. The displacements for the three cases are equal within the limits of accidental error, and, within such limits, the equality shows the absence of mutual influence.

Since a detectable mutual repulsion between adjacent solar lines should increase their separation over that determined from terrestrial sources, another approach to the question is found through such a comparison. It is usually assumed that repulsion occurs between all closely adjacent solar lines. For 45 pairs, mean separation 0.29 A, the differences $\Delta\lambda$ Sun - $\Delta\lambda$ Arc are positive for 17, negative for 21 and zero for 7 lines, the mean differences being zero. It has recently been suggested⁴ that repulsion is to be expected only if the line in the solar spectrum has a closely adjacent line due to another substance not present in the arc. The following data from recent determinations do not show the differences required by the theory, though the lines are due to different elements and originate in separate arcs.

λ Rowland		$\Delta\lambda$ Sun	$\Delta\lambda$ Arc	$\Delta\lambda$ Sun - $\Delta\lambda$ Arc
4058.915	Fe			
.081	Mn	.170	.173	-0.003
4226.904	Ca			
.606	Fe	.700	.710	-0.010
4315.138	Ti			
.262	Fe	.115	.115	0.000
4427.266	Ti			
.482	Fe	.215	.213	+0.002
4454.552	Fe			
.953	Ca	.399	.399	0.000
4489.911	Fe			
.253	Mn	.340	.340	0.000
5208.596	Cr			
.776	Fe	.169	.170	-0.001
5446.797	Ti			
.130	Fe	.332	.334	-0.002
Mean.....		.305	.307	-0.0018

Recently Albrecht⁵ found by comparing the Rowland and International wave-lengths of iron lines that the violet and red components of a solar pair showed apparent displacements to the violet and red of 0.007 and 0.005A, respectively. He interpreted these as effects of anomalous dispersion, an interpretation accepted by Julius, who says,⁶ "Only if the Fraunhofer lines are *mainly* due to anomalous dispersion will they be able to show a mutual influence of the observed kind and magnitude." The absence of mutual influence would, within the limits

of error, remove any direct evidence that anomalous dispersion contributes to the production of the Fraunhofer lines.

As the Mount Wilson data for sun-arc displacements and for the comparative separation between close pairs of lines in solar and terrestrial spectra do not show the effect of mutual influence, it seems necessary to assume either that the Mount Wilson data are affected by systematic errors just sufficient to annihilate the effect of anomalous dispersion, or that the Rowland wave-lengths for lines in close pairs are systematically in error; a slight over-separation of such pairs would introduce an effect of the sign indicated by the theory. The results of an investigation upon "The Accuracy of the Measured Separations of Close Solar Pairs; Systematic Errors in the Rowland Table for such Lines" are given in a Contribution from this Observatory.⁷ For pairs consisting of lines of intensities 3 and 4, with mean separations of 0.274, 0.145 and 0.075 Å, the Rowland separations exceed the Mount Wilson values by 0.003, 0.008 and 0.013 Å, respectively. As errors of this sign and magnitude would account for the deviations found by Albrecht, an exhaustive examination of the cases included in Albrecht's list was undertaken; details of this investigation will appear in a Contribution from this Observatory.

The wave-lengths of the 104 lines used by Albrecht have been referred to those of neighboring free-standing lines. The measurements have been made by two observers upon spectrograms of a scale and dispersion that previous experience had shown were best adapted to each case. The errors found in the Rowland values are systematic and of a sign and magnitude corresponding to the Albrecht deviations. This correspondence is marked, large and small values of the one being associated with large and small values of the other. The coefficient of correlation between the two sets of observations is $+0.55 \pm 0.05$, indicating that the correlation is a practical certainty. No explanation of this correlation seems possible other than that the errors in the Rowland wave-lengths and the Albrecht deviations are two phases of the same phenomenon, that in fact the deviations observed by Albrecht are a measurement of the Rowland errors.

Summary and Conclusion.—1. The violet and red components of close pairs of solar lines show the same displacement as isolated lines when compared with the spectrum of the arc.

2. The mean separation of close pairs in the solar spectrum is the same as that determined from terrestrial sources whether the component lines are due to the same or different elements.

3. The Rowland wave-lengths for close pairs of solar lines are sys-

tematically in error; the violet and red components being assigned values, respectively too small and too large.

4. The systematic deviations for lines with violet and red companions found by comparing the Rowland and International wave-lengths go *pari passu* with and are referable to the errors in Rowland wave-lengths. The coefficient of correlation is $+0.55 \pm 0.05$.

5. These systematic deviations, therefore, do not furnish evidence that the relative positions of the Fraunhofer lines are systematically displaced by mutual influence. On the other hand, the sun-arc displacements and the relative separation of the components of close pairs in solar and arc spectra indicate that, within the limits of error, evidence of mutual influence is absent from the solar spectrum, and, in so far as mutual influence is a necessary corollary of anomalous dispersion in the sun, evidence for it also is absent.

¹ A. Einstein, *Leipzig, Ann. Phys.*, **35**, 898 (1911).

² W. H. Julius, *Astrophys. J.*, **40**, 1 (1914).

³ *Trans. Internat. Union Co-op. Solar Res.*, **4**, 74. Charles E. St. John and Harold D. Babcock, 'A Study of the Pole Effect in the Iron Arc,' *Mt. Wilson Contr.*, **106**; *Astrophys. J.*, **46**, (1915).

⁴ Sir Joseph Larmor, *Observatory*, **497**, 103 (1916).

⁵ Sebastian Albrecht, *Astrophys. J.*, **41**, 333 (1915).

⁶ W. H. Julius, *Astrophys. J.*, **43**, 53 (1916).

⁷ Charles E. St. John and L. W. Ware, *Mt. Wilson Contr.*, —, *Astrophys. J.*, — (1916).

AN ATTEMPT TO DETECT THE MUTUAL INFLUENCE OF NEIGHBORING LINES IN ELECTRIC FURNACE SPECTRA SHOWING ANOMALOUS DISPERSION

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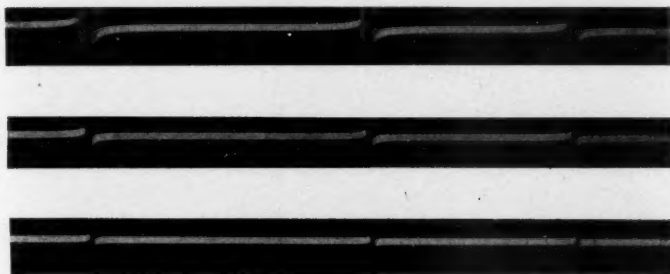
When light traverses a transparent medium, the variation of the index of refraction with the wave-length of the incident light may undergo decided changes if the medium shows selective absorption. If a beam of white light is passed through a mass of vapor which is itself emitting a spectrum, the sudden change of refractive index close to the absorption lines can be shown by suitable optical arrangements. One method of producing this effect is based on the principle of crossed prisms used by Kundt, and consists in making the absorbing medium form a prism whose refracting edge is at right angles to the slit of the analysing spectroscope. An absorption line showing anomalous dispersion will then cause the continuous spectrum to bend sharply in opposite directions

on the two sides of the line. This method was employed by Wood in studying the anomalous dispersion of sodium vapor, the prism being formed by vapor enclosed in a horizontal steel tube heated from below, the upper portion being cooled.

According to a theory advanced by Julius, when anomalous dispersion is active, two vibrations of nearly the same period affect each other in such a way as to cause a mutual repulsion between the corresponding spectrum lines. It seemed possible to make laboratory tests which would set at least an upper limit to the amount of this effect. For this purpose, as well as to study the regular phenomena of anomalous dispersion, the writer has recently adapted the tube resistance furnace for the production of these effects. A beam of white light from a carbon arc outside the furnace chamber was passed through the furnace tube containing the metallic vapor to be studied. A strong density gradient in the vapor was produced by cutting away the upper portion of the tube and passing a water-cooled pipe above it. Examination under high dispersion with a plane-grating spectograph gave a means of studying the relative anomalous dispersion produced by different spectrum lines, and, by the use of mixed vapors in the furnace tube, to test the constancy of wave-lengths of lines when alone and when close to a line showing high anomalous dispersion given by another vapor.

A study of the iron spectrum over a considerable range of wave-length gave strong anomalous dispersion effects for those of the stronger lines which reverse easily in the arc and other sources. This feature appears to be general for the spectra which have been examined. It was found further that a certain temperature of the absorbing vapor is required to give the most efficient prism for a particular type of line. Thus the calcium line λ 4227 and the chromium lines λ 4254, 4275, 4290 can all be made to show very strong anomalous dispersion, but the best temperature for the calcium prism is lower than that for chromium. This can be well shown by mixing the two vapors and causing each in turn to show anomalous dispersion. When the temperature is adjusted to give maximum anomalous dispersion for chromium, the effect usually disappears for λ 4227 of calcium, leaving only a wide absorption line. In several experiments, however, a high temperature condition has given a curvature of the spectrum adjacent to λ 4227 in the opposite direction to that prevailing for the chromium lines at the same time, and also the reverse of what the calcium line itself shows at a lower temperature. This indicates an inversion of the prism of vapor producing λ 4227, due probably to the cooler vapor above giving the line more strongly than the highly heated region below.

The density of the absorbing vapor is necessarily a function of the temperature when plenty of the material is present. At a given temperature, the amount of anomalous dispersion is proportional to the vapor density, which alters the width of the absorption line, so that for special purposes the effect can be regulated by changing the amount of vapor. The reproduction shows the anomalous dispersion for the chromium lines λ 4254, 4275, 4290, the temperature being approximately 2500°C. in each case, with varying vapor densities.



ANOMALOUS DISPERSION OF CHROMIUM LINES WITH VARYING VAPOR DENSITY.

The tests on the mutual influence of spectrum lines were carried out by mixing titanium and calcium vapors with that of chromium. By this means, a titanium line was obtained separated by 0.21 Å from λ 4275 of chromium, while a calcium and a titanium line occur 0.36 Å and 0.65 Å respectively from λ 4290 of chromium. The titanium and calcium lines were thus well within the curved spectrum given by the strong anomalous dispersion of the chromium lines. The wave-lengths of the former, given as absorption lines under these conditions, were compared with their values when produced by the furnace as emission lines.

Twenty-seven spectrograms showing varying degrees of anomalous dispersion were measured. The titanium line separated by only 0.21 Å from the chromium line λ 4275 gave consistent measurements indicating an approach to the chromium line in the anomalous dispersion plates, the mean difference between the two sets of measures being 0.006 Å. It is questionable, however, whether this displacement is genuine, as the spreading of the strong chromium line weakened the continuous spectrum on one side of the titanium absorption line, which would probably affect the micrometer settings. The calcium line separated by 0.36 Å from λ 4290 of chromium showed an apparent approach amounting to 0.002 Å, to which the same source of error may apply. The line

of the set most favorable for accurate measurement was λ 4289.237 of titanium, 0.65 Å from λ 4289.885 of chromium. Measurements of this line from three different standards gave no difference larger than 0.001 Å and usually agreed exactly. It may be said, therefore, that the measurements have given no evidence whatever of a mutual repulsion between close lines when anomalous dispersion is active, such small apparent differences as were found being in the opposite direction.

The same lines were tested in the regular furnace spectrum under a dispersion of 1 mm. = 0.6 Å to see whether the presence of the strong chromium lines affected the wave-length of the close line of titanium and calcium. The latter were photographed with and without the mixture of chromium vapor. The calcium and one titanium line gave differences of 0.002 Å but these were opposite in direction and probably within the errors of measurement, while the other titanium line, closest of the three to a chromium line, agreed within 0.001 Å when titanium was used alone and when mixed with chromium.

The material in this investigation has been limited by the scarcity of suitable pairs of lines, as in addition to being separated by a small interval, the lines must be given strongly in the furnace spectrum and one of them must show high anomalous dispersion. The lines tested have filled these requirements and the measurements have at least shown no tendency toward a repulsion between such close lines under these conditions.

SYNTHESIS OF THE BASE $C_3H_4ON_2$ DERIVED FROM METHYL-AMINOMETHYL-3,4-DIHYDROXYPHENYLCARBINOL

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Some thirteen years ago Abel¹ found that when methylamino-methyl-3,4-dihydroxyphenylcarbinol, $3,4-(HO)_2C_6H_3CH(OH)CH_2NHCH_3$ (epinephrine, suprarenine, adrenaline, the substance known as the active principle of the medullary portion of the suprarenal capsules) is slowly added to nitric acid (density 1.2) an energetic reaction takes place and there are obtained as chief products oxalic acid and an unstable nitrogenous base in the form of a hygroscopic salt (probably the oxalate). With iodine trichloride this base gives a crystalline double compound which, although relatively stable, is also very hygroscopic, but with gold chloride is obtained a stable, beautifully crystalline chloroaurate. Abel analyzed this salt for carbon, hydrogen, nitrogen, gold and chlorine

and the remarkably concordant results of all his determinations seem to establish beyond doubt that its composition is represented by the formula $C_8H_4ON_2 \cdot AuCl_3 \cdot HCl$. The free base itself could not be isolated and all the evidence tends to show that it decomposes as soon as it is set free from its salts; when any of the latter are treated with alkaline reagents (even such weakly basic ones as calcium carbonate or acetate) a characteristic, unpleasant, coniine-piperidine-like odor develops and vapors which turn moist litmus paper blue are evolved; among the products formed when the gold salt is boiled with sodium hydroxide solution were identified ammonia, methylamine and methylhydrazine.

Since the base must be formed by the action of the nitric acid on the side chain $CH_3NHCH_2CH(OH)$ —of the epinephrine molecule, it seemed possible that it might also be obtained by treating methylaminoacetaldehyde, CH_3NHCH_2CHO , with nitric acid. Accordingly, methylaminoacetal, $CH_3NHCH_2CH(OC_2H_5)_2$, was prepared by heating under pressure chloroacetal, $ClCH_2CH(OC_2H_5)_2$, with an aqueous solution of one equivalent of sodium hydroxide saturated with methylamine, and was converted into the aldehyde by letting it stand overnight in concentrated hydrochloric acid; the solution was then concentrated *in vacuo* at 40° and finally at room temperature over sulphuric acid and solid sodium hydroxide. When the resulting syrup was treated with nitric acid there was obtained a substance agreeing in all respects with that described by Abel. It can also be prepared by treating the acetal directly with nitric acid, but in that case the reaction is very violent and even after it has apparently ceased sometimes starts again explosively and the whole product may be converted into a red tar. The synthetic base reduces ammoniacal silver nitrate and Fehling's solutions, evolves the characteristic coniine-piperidine odor with alkalis and gives with gold chloride a salt difficultly soluble in water and separating from acetone containing a little alcohol in beautiful yellow prisms containing the same percentages of gold and chlorine as Abel's salt.

0.2484 g. salt decomposed with 10% aqueous Na_2O , gave 0.1156 g. metallic Au and the filtrate gave 0.3370 g. AgCl.

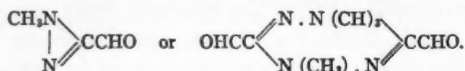
	Found	Calculated for $C_8H_4ON_2 \cdot AuCl_3 \cdot HCl$
Au	46.54	46.49
Cl	33.56	33.44

When the gold salt is treated with sodium hydroxide solution and the mixture is distilled to a small volume the distillate is found to reduce Fehling's solution strongly, and the residue in the distilling flask, after being filtered from the gold and acidified with acetic acid, gives with

calcium chloride a crystalline precipitate soluble in hydrochloric acid and reprecipitated by ammonia.

The hydrochloric acid solution of the base, obtained by decomposing the water solution of the gold salt with hydrogen sulphide, gives with phenylhydrazine and potassium acetate at about 40° a reddish brown, partly crystalline, partly resinous solid, easily soluble in organic solvents (except ligroin), which, when dissolved in a little alcohol and poured into much boiling water, separates on cooling in fine felted needles melting at 159° when heated slowly and at 162-3° when the capillary is introduced into a bath previously heated to 150°.

With the data at his disposal Abel in 1903 suggested that the base might well be a highly unstable cyclic compound related to the pyrazolone series. In 1906 Curtius began publishing the results of his interesting investigations on the series of compounds obtained by the action of alkalis on diazoacetic ester,² and our new base in so many respects (namely, in its decomposition into methylhydrazine, methylamine, ammonia and oxalic acid) so closely resembles his 'pseudodiazoacetic acid' derivatives that it may not appear too hazardous to suggest that it contains the isodiazomethane or N-1,4-dihydro-1,2,4,5-tetrazine grouping and that its constitution may be represented by the formula



This suggestion is made with all reserve and it is hoped that certain experiments now being carried out will soon make it possible to decide whether or not it is tenable.

[This work was made possible by a Grant to Prof. John J. Abel from the Rockefeller Institute for Medical Research.]

¹Abel, J. J., *Amer. J. Physiol. Proc.*, 8, 31 (1903); *Ber. D. chem. Ges.*, 36, 1846 (1903); 37, 368 (1904); Abel and Taveau, R. deM., *J. Biol. Chem.*, 1, 13 (1905).

²For a summary of the work of Curtius on these compounds, see *Ber. D. chem. Ges.*, 41, 3161 (1908); also *Ibid.*, 42, 3284 (1909).

EXTINGUISHED AND RESURGENT CORAL REEFS

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In the diagrams by which Darwin originally illustrated his theory of upgrowing reefs on subsiding foundations, the reefs were drawn as growing upward and inward, in such a way that the diameter of their

ring diminished, but he did not explain the cause of the diminution. Dana used similar diagrams and insufficiently explained the diminution of diameter by saying:—"a barrier, as subsidence goes on, gradually contracts its area, owing to the fact that the sea bears a great part of the material inward over the reef" (Corals and Coral Islands, 1872, 263). Certain later diagrams, especially one by Lendenfeld (Westermann's *Monatshefte*, 1896, 499-519), represents a reef as growing upwards and outwards, and hence of increasing diameter. Daly adopts essentially this view and adds:—"When one remembers that most of the detritus abraded from the main reef goes to form talus on the outer submarine slope; and, secondly, that the growth of new coral is much faster on that side, we cannot fail to expect a centrifugal tendency for the encircling reef, as the island sinks" (Glacial-Control Theory of Coral Reef, Proc. Amer. Acad., li, 1915, 247). Both increase and de-

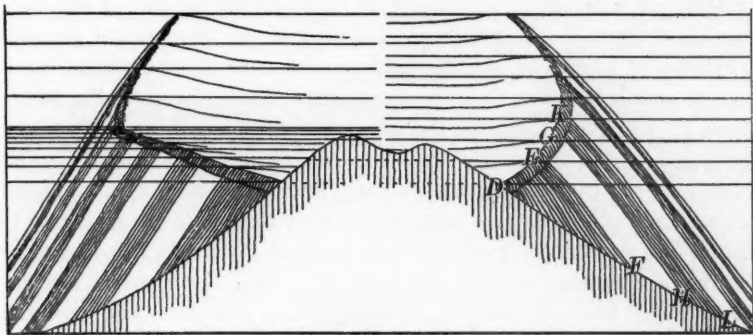


FIG. 1.

crease of reef diameter may take place, for both outward and inward upgrowths are possible, but in atolls that have grown upward during long continued subsidence in a deep ocean, diminution of diameter with inward growth is the more probable for the following reasons.

Let a sea-level fringing reef be formed around a young volcanic cone at *D*, figure 1, and let the horizontal lines on the right side of the figure represent successive levels of the sea with respect to a uniformly subsiding cone. Let the subsidence be so slow that the reef at first grows upward and outward, *DE*, on its own talus, which lengthens as subsidence progresses. The talus material consists chiefly of fragments broken by waves from the corals and other organisms which grow on the outer face of the reefs. In a given period of time, a growing reef face of given perimeter and 20 fathoms deep cannot produce more than a certain maximum volume of new growth; and as some of the

new growth stands firm to build the reef upward, while some is broken off and washed inward to form the flat reef and the lagoon shoals, only the remainder can be sacrificed for the talus. Let this remainder be represented in section by *DEF*. If equal remainders are applied to talus building in equal time intervals, they may be represented by the shaded and unshaded quadrilaterals, *EFHG*, *GHLK*, etc., in which the breadth diminishes as the length increases.

So long as the reef growth is inclined outward, its increase in perimeter will, by providing a larger volume of coral growth, aid in supplying the demand for more talus material due to increase of depth; it is indeed conceivable that, if a reef foundation subsides very slowly and of the talus slants down to a level ocean floor of moderate depth, increase of perimeter may more than compensate for increase of talus length in the deepening water. In this case, outgrowth will continue at a constant or a lessening instead of at a steepening angle, as on the left side of figure 1. Especially favorable conditions for outward growth are provided when two islands stand so near each other that the submerged saddle between them is of moderate depth; for then the talus slopes on the line connecting the two island centers will be of decreasing length, if the rise of the talus intersection is faster than the subsidence of the islands. In such a case, reef cusps would tend to grow toward each other, and on uniting, the two concave reef faces would diminish their concavity by growing outward faster than the convex reef faces elsewhere, because the talus beneath a concave reef face is concentrated and thickened on converging lines of slope, while beneath a convex reef face it is distributed and thinned on diverging lines of slope. The double-looped barrier reef that encloses Makongai and Wakaya in central Fiji appears to be an example of this kind: on the other hand, four oval atolls north of the Exploring Isles in eastern Fiji, separated from each other by less distance than that which separates Makongai and Wakaya, show little tendency to develop approaching cusps; hence subsidence there may have been relatively rapid; and this is made probable by the occurrence of several 'drowned atolls' not far to the northeast.

But when the reef talus is built on the slope of a volcanic cone that rises from a deep ocean, the increase of coral growth on an enlarging reef perimeter may not fully compensate for increase of talus material demanded, especially if subsidence be relatively rapid; then the reef growth must be steeper in the second subsidence interval, *EG*, than in the first, *DE*; steeper in the third than in the second, and so on, in order that the thinner talus increments shall support it: otherwise the

reef would have to grow outward in an overhanging, unsupported cornice. It is true that when upward growth becomes steep, the share of it that stands firm to build the reef upwards is smaller than before; thus the part that may be sacrificed for talus building is larger; but this will not make up for the increased demand due to increased talus length. A time must therefore come when upgrowth passes the vertical and thereafter inclines inward, as above *K*: then a decrease of perimeter sets in and the total volume of coral growth diminishes, while the demand for talus material still increases. Under these conditions, the angle of inward upgrowth must soon come to be but little steeper than the angle of talus slope. An atoll reef which has been reduced to a diameter of a mile when this condition is reached, will be reduced to a point when subsidence has progressed about 2000 feet farther. If subsidence then still continues the reef will be extinguished. Dana reached essentially the same conclusion, but without analysis; he briefly asserts that subsidence will gradually reduce the size of an atoll 'until it finally becomes so small that the lagoon is obliterated;' then, if "subsidence continues its progress . . . it finally sinks the coral island, which, therefore, disappears from the ocean" (*Corals and Coral Islands*, 1872, 322, 323). Thus a difference may be drawn between atolls that are 'extinguished' by the reduction of their diameter to zero during a uniform subsidence (or during an intermittent subsidence at a constant average rate), and atolls that are 'drowned,' as Moresby phrased it, by a too rapid subsidence, whatever their diameter may be.

It is evident that many variable factors would enter the equation by which the ultimate extinction of a reef might be expressed; form of ocean floor, "rate of subsidence and length of intervening stationary periods" as Darwin phrased it, rate of coral growth, and strength of wave attack are the more important factors. The change in angle of upgrowth due to a change from slow to rapid subsidence is shown on the left side of figure 1. Further, an extinguished reef would be brought to light if subsidence were reversed into upheaval; such a reef might then increase in size if upheaval paused or halted; and thus increased, it might if subsidence were renewed again grow up for a while before being extinguished for a second time. Extinguished reefs thus brought to light may be called 'resurgent.'

Many smaller reefs in Fiji appear to be resurgent, as thus defined. A good example is Frost reef, *F*, figure 2, a third way between Mango, *M*, 7 miles to the east, and Vatu Vará, *V*, 13 miles on the west. Mango appears to be a denuded caldera ring 3 miles in diameter, which has been submerged 450 feet or more and rimmed at that level with a fringing

reef, then uplifted 450 feet, and again fringed at present sea level; its highest summits now rise 650 feet above the sea. Vatu Vará is a former atoll, presumably formed during subsidence, but now standing 1030 feet above sea level and nearly 2 miles in diameter at its base; it is the highest elevated reef in Fiji. According to Andrews its steep slopes are contoured above and below mid-height by two corniced "water-lines;" hence its uplift must have been recent and rapid: like Mango, it is now fringed by a sea-level reef. Frost reef is a mile in diameter: it has no lagoon. Soundings of 103, 115, 134, 146, and 133 fathoms are charted at less than half a mile away; 200 fathoms and no bottom are recorded at three points toward Mango. If Frost reef be diminished by removing a fringe of somewhat less than the average sea-level fringe-width now surrounding Mango or Vatu Vará, it will be reduced to a mere point; and as such it was probably extinguished while Mango and Vatu Vará were subsiding; it must eventually have been submerged



FIG. 2.



FIG. 3.

under more than 100 fathoms of water, when the highest reefs of Mango and Vatu Vará were at sea level, *ss*; but it was revealed as a resurgent reef when the following uplift brought sea level to *EE*.

Midway in the eight-mile passage between the great barrier reef of the Exploring Isles, *B*, and Kimbombo reef, *K*, on the north is Trigger rock, *T*, figure 3, a minute reef in four fathoms of water, with the 100-fathom circle hardly half a mile in diameter, and soundings of 110, 121, 154 and 136 fathoms close outside. This rock must have been extinguished during the subsidence in which the now-elevated limestones of the Exploring Isles and Kimbombo were accumulating, and then submerged to a depth of 100 fathoms or more when the highest limestones were formed at the level *ss*; but a later upheaval brought it to light again as a resurgent reef, with sea level at *t*; then it may have been recolonized for a time while the neighboring elevated limestones were suffering dissection; now, since the dissected limestones have again subsided, so that sea level is *EE*, the reef is almost extinguished

for a second time. It is interesting to note that the upheaval of the Exploring Isles, by which the previously extinguished Trigger reef became resurgent, was of a significantly earlier date than the resurgence of Frost reef between Mango and Vatu Vará; for the limestones of these two islands are little dissected, while those of the Exploring Isles have been eroded to mere remnants of their former volume. It is the present almost-extinction of Trigger rock in a renewed subsidence of its region that is contemporaneous with the resurgence of Frost reef. Darwin's theory of intermittent subsidence is the only one of many coral-reef theories, which can account for the facts here adduced.

THE ORIGIN OF CERTAIN FIJI ATOLLS

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The unconformable contact of many fringing reefs on the eroded submarine slopes of oceanic islands, and the embayment of such islands inside of barrier reefs are inconsistent with certain modern theories of coral reefs; and the recognition of these significant features has in recent years led several observers back to Darwin's earlier theory of upgrowth on intermittently subsiding foundations. My own experience two years ago, while on a Shaler Memorial voyage across the Pacific concerning which a brief report has been published in these PROCEEDINGS (1, 1915, 146-152), added evidence of reef formation during two periods of subsidence; the first subsidence being shown by the occurrence of elevated reef limestones resting unconformably on eroded volcanic foundations, as seen in Vanua Mbalavu and Avea, two of the reef-encircled cluster of the nine Exploring Isles in the eastern part of the Fiji group, the second subsidence being shown by the embayment of these now-dissected limestones, around which a new barrier reef has grown up, as stated more fully in the *American Journal of Science* for September, 1915.

Continued attention to this problem has lately enabled me to perceive that the evidence of two periods of subsidence and reef growth found in the Exploring Isles may be extended to several neighboring atolls, the area concerned being well shown in Plate 19 of Agassiz' "Islands and Coral Reefs of Fiji" (*Bull. Mus. Comp. Zool.*, xxxiii, 1899): thus singularly enough a reconciliation is permitted between Agassiz' theory of the formation of atolls on uplifted and worn-down limestone islands and Darwin's theory of the formation of atolls by upgrowth on

subsiding islands. But it is not intended to imply that the view here announced applies to all atolls of the Fiji group, much less to all atolls elsewhere, most of which have probably been formed by upgrowth during intermittent subsidence without important interruption by uplift.

The essence of the case is as follows: In the Exploring Isles of the Fiji group, a portion of the largest volcanic island, Vanua Mbalavu, of well denuded form, 13 miles long and 930 feet high, is shown in the apex of sector M, figure 1; it is in part unconformably covered up to heights of 500 or 600 feet with heavy reef and lagoon limestones, deeply dissected and well embayed. Avea, a smaller member of the same cluster, two miles long, capped with limestones resting unconformably on denuded volcanic hills, rises 600 feet from the same broad lagoon,

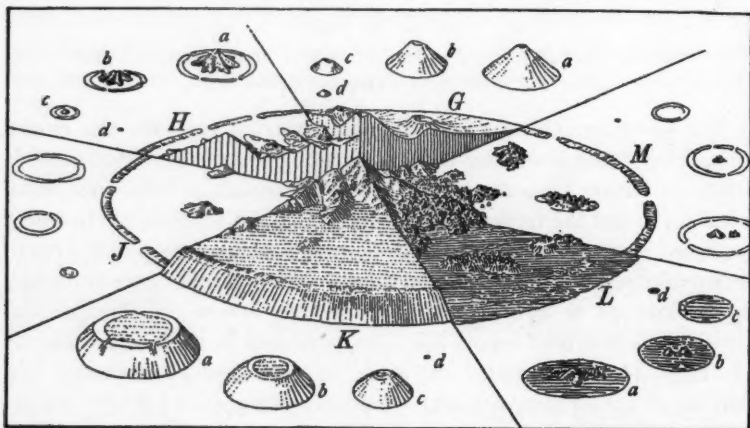


FIG. 1.

and is enclosed with the eight other Isles of the cluster by an irregular barrier-reef ring, 23 miles in longest diameter, part of which is shown in the same sector. All but one of these islands consist partly or wholly of elevated limestone: they therefore presumably represent, as Agassiz points out, "fragmentary remains of the land which must have once occupied the area of the lagoon." Outside of the barrier reef, twelve almost-atolls, atolls, and isolated reef patches rise from deep water, not more than 5 or 10 miles distant: four of these are represented in sector M: an almost-atoll in which the small central rocks are partly volcanic, partly limestone; a smaller almost-atoll, with limestone rocks alone rising from its lagoon; a true atoll; and a small reef on the verge of extinction. The islands and reefs are crowded together in the diagram to save space: the circular pattern which the barrier reef of the Explor-

ing Isles here seems to have results from the repetition of one sector in six successive positions: the reef is really of irregular pattern and the islands are not centrally placed within it. A consideration of all the pertinent facts shows that, if the strong changes of level demanded by Vanua Mbalavu and Avea have extended to the exterior atolls, as is eminently probable, then the true atoll and the almost-atolls have been formed, during a recent subsidence of a few hundred feet, by upgrowth on the worn-down remnants of uplifted atolls, which had likewise been formed by upgrowth, presumably on a volcanic foundation, during an earlier time of greater subsidence.

The changes of level demanded by Vanua Mbalavu and Avea may be inferred from the structure of Avea, two miles long and 600 feet high, as shown in part in figure 2. It should be announced that this figure has been drawn from a rough outline made from a passing steamer; confidence is nevertheless felt in its essential correctness, for I fully agree with Gardiner and Agassiz that volcanic slopes and limestone cliffs in the Fijis are easily recognized at a distance. The under-



FIG. 2.

lying volcanic rocks here, as in Vanua Mbalavu, have the forms of rounded hills, subdued by deep erosion before they were covered with limestones. The eroded slopes dip under water, as at x ; hence the island formerly stood at least x feet higher than now. The subdued hills and slopes are partly covered by limestones, now rising to a height of 600 feet; the limestones have suffered much erosion, which has greatly diminished their area, and has somewhat reduced their height, as at y . Hence the island after being eroded, must have sunk $x + 600 + y$ feet while receiving its unconformable limestone cover. The limestones are now dissected and their shore line is so well embayed as to necessitate a recent submergence of more than 100 feet; and it must have been during this submergence that the present great barrier reef has grown up. It may be noted in passing that the postglacial rise of ocean level may have had to do with the recent submergence, but for reasons elsewhere stated I believe that true subsidence has also been concerned in it.

The six sectors, G to M, of figure 1 graphically represent the succes-

sive changes thus inferred. Sector G shows part of a group of confluent volcanoes, the area of which is about the same as that of the present Exploring Isles lagoon; several smaller cones rise near by; all together they resembled the present Lipari islands of the Mediterranean. After suffering prolonged dissection and partial submergence, the resulting embayed islands encircled by an upgrowing barrier reef are represented in sector H; this stage corresponds to that of Kandavu and its neighbors in southwestern Fiji. Down-sinking of the volcanic islands and upgrowth of the barrier reef continued until the total subsidence measured $x + 600 + y$ feet, when but few volcanic hills survived, as in sector J; the small Gambier islands in a large lagoon southeast of the Paumotu, or the small islands of Budd reef in northeastern Fiji represent this stage. An uplift of $600 + y + > 100$ feet then occurred, as in sector K: the resulting limestone plateau is typified by the uplifted atolls of the Loyalty group. The compound mass thus exposed to erosion was reduced over most of its limestone area to low relief surmounted here and there by residual hills, as in sector L; the hills of volcanic rock have smooth soil-covered slopes, those of limestone have steep cliffs and ragged crags. A recent submergence of 100 feet or more introduced the present conditions, as in sector M, where the lagoon floor has been smoothed by renewed deposition.

The exterior volcanic islands, a, b, c, d, of sector G, must have suffered essentially the same series of changes as the larger central volcanic islands. The atoll built on the largest cone, a, may have shown no volcanic knob in the stage of sector J, but one is afterwards laid bare in sector L, and its summit remains visible, along with a limestone knob, in the largest reefing of sector M. Island b having a less initial height in sector G, it now shows only limestone knobs, sector M. Island c, beginning as a small volcanic cone, sector G, was deeply covered with limestone in sector J, and reduced to a low surface without high limestone knobs in sector L; and this is reasonable enough, for its area is not so large as any one of several uninterrupted lagoon areas within the adjacent great barrier reef. Its present reef is the result of upgrowth during the subsidence which transformed sector L into sector M.

Seven of the twelve outlying reefs near the Exploring Isles are true atolls, like the true atoll of sector M. The foregoing discussion gives, I believe, a nearer approach to a demonstration of the origin of these sea-level atolls by upgrowth during sub-recent subsidence than has been provided for any other sea-level atolls, except Funafuti which has been penetrated by a deep boring. The smallest reef in sector M

represents mere ledges of coral rock on the Admiralty chart: the 100-fathom line around each of three such reef rocks near the Exploring Isles is less than a mile in diameter, and the rocks are mere points; hence these minute reefs, beginning on small volcanic cones in the stage of sector G, must have been extinguished in sector J, resurgent in sector K, a little enlarged by outward growth in sector L, and almost extinguished again in sector M.

The upheaval and the sub-recent subsidence mentioned in the foregoing paragraph were not uniform, as has thus far been implied. The recent subsidence is believed to have increased to the east or northeast; first, as Agassiz pointed out, because the floor of the great lagoon of the Exploring Isles increases in depth from 20 fathoms or less on its western side to 80 or 100 fathoms on its eastern side; second, because several 'drowned atolls' or submerged banks lie to the northeast; indeed the northeastern-most of the seven outlying atolls is mostly submerged; third, because Mango, 10 miles to the southwest, has elevated reefs moderately dissected at an altitude of 500 feet, and 30 miles to the west, Yathata and Vatu Vará are uplifted, undissected atolls at altitudes of 840 and 1030 feet. The intermediate island of Kanathea, nearer to the Exploring Isles barrier reef than Mango is, also seemed to me to bear small uplifted reefs at a height of about 600 feet, but I was too far from this island to make sure of it.

The upheaval that preceded the subrecent subsidence must also have been unequal and greater to the east than to the west, because while the Exploring Isles were thus uplifted long enough ago to have been afterwards well dissected, Yathata and Vatu Vará were at that time presumably sinking and growing, preparatory to being uplifted recently as above stated. These unequal changes of altitude cannot be explained by changes in the level of the ocean, which are everywhere alike; they can be explained only by unequal subsidence and upheaval of the islands concerned.

INTERFEROMETER METHODS BASED ON THE CLEAVAGE OF A DIFFRACTED RAY

By C. Barus

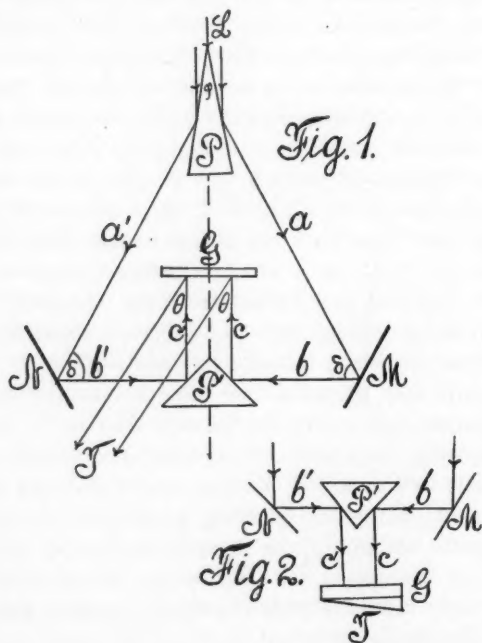
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The prismatic method of cleaving the incident beam of white light is available for the superposition of non-reversed spectra, under conditions where the paths of the component rays may have any length whatever.

It is thus an essential extension of the same method as used for reversed spectra, heretofore, and also of the methods in which the paths are essentially small.

In figure 1, P is the first prism cleaving the white beam, L , diffracted by the slit of the collimator. M and N are the opaque mirrors, the former on a micrometer. For greater ease in adjustment, the second prism P' is here right angled, though this is otherwise inconvenient, since the angle, $\delta = 90^\circ - \varphi$, is too large. The rays reflected from P' impinge normally on the reflecting grating G (grating space, $D = 200$



$\times 10^{-4}$) and are observed by a telescope at T . P , P' , M and N are all provided with the usual three adjustment screws. P' must be capable of being raised and lowered and moved fore and aft. The field is brilliantly illuminated. When the path difference is sufficiently small the fringes appear and cover the whole length of superposed spectrum, strongly. They are displaced with rotation if M is moved normally to itself.

As first obtained the fringes were too close packed for accurate measurement; but the following example of the displacement, e , of the mirror

M , for successions of 40 fringes replacing each other at the sodium lines, show the order of results: $10^{-2}e = 1.55, 1.40, 1.60, 1.55$ cm., so that per fringe

$$\delta e = 39 \times 10^{-6} \text{ cm.}$$

The computed value would be (φ , the prism angle)

$\delta e = \lambda/2\cos(\delta/2) = 58.93 \times 10^{-6}/2 \times 0.81 = 36.4 \times 10^{-6}$ cm., assuming $\delta = 90^\circ - \varphi$. The difference is due both to the small fringes which are difficult to count and to the assumed value of δ . The range of measurement is small (if M only moves), not exceeding 1.6 millimeters for a moderately strong telescope. Usually but one half of this displacement is available as the fringes increase in size (usually with rotation) from fine vertical hair lines to a nearly horizontal maximum and then abruptly vanish. But one half of the complete cycle is thus available.

If we regard the component beams, a, b, c , and a', b', c' as being of the width of the pencil diffracted by the slit of the collimator, it is clear that the maximum size of fringes will occur when c and c' are as near together as possible: furthermore, that as M moves toward P' , c continually approaches c' , until b drops off (as it were) from the right angled edge of the prism P' . To get the best conditions, i.e. the largest fringes, c must therefore also be moved up to the edge of P and very sharp angled prisms be used at both P and P' . The largest fringes (lines about 10 times the D_1D_2 distance) obtained with the right angled prism were often not very strong, though otherwise satisfactory. Much of the light of both spectra does not therefore interfere, being different in origin.

Results very similar to the present were described long ago¹ and found with two identical half gratings, coplanar and parallel as to rulings, etc., when one grating was displaced normal to its plane relative to the other. The edges of the two gratings must be close together, but even then the fringes remain small and the available paths also. Strong large fringes, but with small paths, were obtained by the later method² of two identical transmitting gratings, superposed.

If the prism P' is right angled, it may be rotated as in figure 2, so that the rays c and c' pass off towards the rear. They are then observed through an Ives' prism grating G and a telescope at T . This method admits of much easier adjustment. With the component beams, a, b, a', b' , coplanar, horizontal and of about equal length in the absence of the prism P' , the latter is now inserted with its edge vertical (rotation) and the white slit images in T (without G) superposed, horizontally and vertically. G is then added and the micrometer at M or N manipu-

lated till the fringes appears. As above, they are largest when c and c' are as nearly as possible coincident and vanish as horizontal fringes at the maximum; for the effective parts of c and c' are component halves of the same diffracted beam from the slit.

It is interesting to observe, since interference³ also occurs when one of the superposed spectra is inverted on a line parallel to its length, that such diffraction is demonstrable in case of homogenous light, even when the slit is absent.

A fuller report of this work has been presented to the Carnegie Institution of Washington, D. C.

¹ *Phil. Mag.*, 22, 118-129 (1911); *Carnegie Inst. Publ.*, No. 149, Chap. VI.

² *Physic. Rev.*, July, 1916; *Science*, 42, 841 (1915).

³ *Amer. J. Sci.*, 40, §4, 491 (1915).

ON THE INHERITANCE OF CERTAIN GLUME CHARACTERS IN THE CROSS *AVENA FATUA* × *A.* *SATIVA* VAR. KHERSON

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The investigation reported in the present paper¹ deals with the inheritance of certain characters of the flowering glumes in a cross between a wild oat *Avena fatua* and a cultivated variety (*Avena sativa*). The cultivated oat used is a selection from the Kherson variety. Both parent strains have been grown as pure lines for five years and are known to breed true.

The parent varieties used in this cross possess the following contrasting glume characters.

CHARACTER	AVENA FATUA	AVENA SATIVA VAR. KHERSON
Grain color	Dark brown or black	Yellow
Base of grain	Wild type	Cultivated type
Shattering	Shatters	Does not shatter
Awns	Heavy, twisted and geniculate awns on both upper and lower grains of a spikelet	None or an occasional awn on the lower grain. None on the upper
Pubescence	Thick pubescence on lateral and dorsal sides of callus on both grains	None or occasionally 1 or 2 hairs at the sides of the base of the lower grain
Base of grain		
Back of grain	Heavy pubescence on the back of both grains	None
Pedicel	Heavy pubescence on both grains	None

As shown in figure 2, the base of the grain or callus on the wild oat is expanded into a sucker-like ring. This large cleavage plane permits the grain to separate from the outer glumes very easily when mature. The cultivated grain (fig. 1) possesses a narrow contracted base and the grain does not shatter under ordinary conditions.

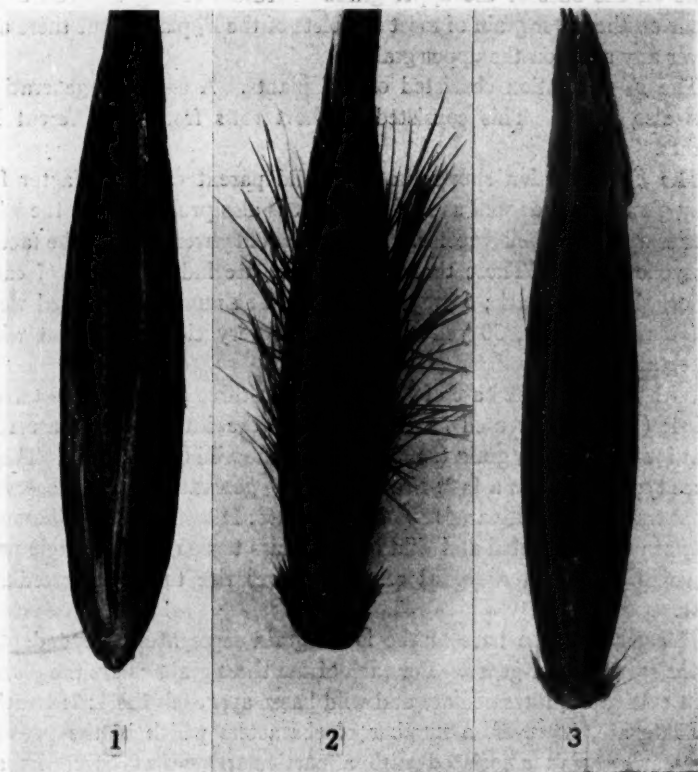


FIG. 1. VENTRAL VIEW OF THE LOWER GRAIN FROM A SPIKELET OF KHERSON OATS SHOWING THE CULTIVATED BASE OF THE GRAIN AND THE ABSENCE OF PUBESCENCE. $\times 8$.

FIG. 2. VENTRAL SURFACE OF THE LOWER GRAIN FROM A SPIKELET OF WILD OATS SHOWING THE WILD BASE, THE PUBESCENCE ON THE PEDICEL AND THE SIDES OF THE GRAIN. $\times 8$.

FIG. 3. VENTRAL VIEW OF THE LOWER GRAIN FROM AN F_1 PLANT SHOWING THE INTERMEDIATE BASE, PUBESCENCE AT SIDES OF THE BASE AND ABSENCE OF PUBESCENCE ON THE PEDICEL. $\times 8$.

In the F_1 generation the grain is brown in color but ordinarily not quite so dark as the pure wild. The base of the lower² grain in each spikelet is intermediate between the wild and cultivated condition (fig. 3).

The grain does not shatter. The base of the upper grain on each spikelet is like the upper grain of the cultivated variety. The F_1 grain is pubescent on the back of the lower grain of a spikelet but unlike the wild the upper grain of each spikelet is entirely free from pubescence. There is a tuft of hair at the sides of the base of the lower grain but none on the base of the upper grain. Medium strong to weak awns occur on the lower grain of most spikelets of the F_1 plants, but there are never any awns on the upper grain.

The F_2 generation consisted of 465 plants. A small F_3 generation was also grown. This consisted of short rows from 70 different F_2 plants.

The F_2 generation shows that the wild parent carries a factor for gray glume color as well as for black. It is also probable that the wild carries a gene for yellow color. The cultivated parent carries the factor for yellow color. These three colors segregate independently of each other, giving 12 black; 3 grey; 1 yellow. The numbers obtained were 347 black; 88 grey, 30 yellow, which is a very close agreement with expectation.

With regard to the base of the lower grain three types may be recognized: (1) the cultivated base (fig. 1); (2) the intermediate base like that found on the F_1 grain (fig. 3); and (3) the wild base (fig. 2). These three types appear in a 1:2:1 ratio on the F_2 generation. The observed numbers are 117 cultivated: 236 intermediate: 112 wild. The difference between the cultivated and wild base appears to be due to a single pair of genes. The heterozygous condition gives rise to the intermediate base.

The gene for the base of the lower grain segregates independently of the several color genes. For each of the three grain colors the plants with cultivated, intermediate and wild bases approach the 1:2:1 ratio.

There are, however, a number of characters which in the present cross are always associated with a particular type of base. In all there are seven pairs of characters which show this absolute correlation. The condition of each of these characters for the three types of bases on the lower grain is given in Table 1.

The present data are not sufficiently extensive to determine whether these several phenotypic characters are caused by the action of a single pair of genes or whether they are due to several pairs of genes very closely linked together. Nilsson-Ehle (1911) regards this group of characters as due to the presence or absence of a single inhibiting factor. In certain other crosses not yet completely analyzed but involving this same strain of *A. fatua* some of these correlations have been broken.

TABLE 1

CHARACTERS CORRELATED WITH THE THREE TYPES OF BASES ON THE LOWER GRAIN

CULTIVATED BASE	INTERMEDIATE BASE	WILD BASE
Cultivated base on the upper grain	Cultivated base on the upper grain	Wild base on the upper grain.
Absence or almost complete absence of awns on the lower grain	Medium awns on the lower grain of some spikelets	Very heavy awns on the lower grain of every spikelet.
Total absence of awns on the upper grain	Total absence of awns on the upper grain	Very heavy awn on the upper grain of every spikelet
Absence of pubescence on the pedicel on the lower grain.	Absence of pubescence on the pedicel on the lower grain	Heavy pubescence on the pedicel on the lower grains.
Absence of pubescence on the pedicel on the upper grain	Absence of pubescence on the pedicel on the upper grain	Heavy pubescence on the pedicel on the upper grain
None or sometimes very slight pubescence at the sides of the base of the lower grain	Medium heavy tuft of hair at the side of the base of the lower grain	Heavy pubescence on all sides of the base of the lower grain
No pubescence on the base of the upper grain	No pubescence on the base of the upper grain	Heavy pubescence on all sides of the base of the upper grain

This and other facts have led the writer to believe that some of these characters at least are controlled by separate genes.

Characters Showing Partial Linkage.—Two characters have been discovered in this cross which apparently show partial linkage with other genes. These characters are (1) pubescence on the back of the lower grain and (2) pubescence on the back of the upper grain. These two characters are inherited independently of each other but the phenotypic appearance of the latter character is dependent upon the presence of the former gene in the same zygote.

In the F_2 generation the plants which have pubescence on the back of the lower grain segregate from those lacking this character in a 3 to 1 ratio. The observed numbers are 347 pubescent to 118 smooth. This character further segregates independently of the type of base on the lower grain.

On the other hand there is a very close relation between the presence and absence of black color and the presence and absence of pubescence on the back of the lower grain. The observed numbers are shown in table 2.

There is an almost absolute correlation between the presence of pubescence on the lower grain and the black color. However, two black plants were found which lack this pubescence entirely. The grain from these two plants has been carefully examined and no evidence of

TABLE 2
RELATION OF THE PUBESCENCE ON THE BACK OF THE LOWER GRAIN TO THE COLOR OF THE GRAIN

	BLACK		NON-BLACK	
	PUBESCENT	SMOOTH	PUBESCENT	SMOOTH
Observed Number.....	345	2	0	118

pubescence could be found. No plants with pubescent non-black grains have been found in this cross. However, in certain other crosses in which this same wild was used, a few non-black pubescent plants have been found.

While the present data are hardly sufficient to prove the point, it seems very probable that we have here a case of partial linkage. Although a straight F_2 generation is not the best kind of data with which to study linkage, certain points can nevertheless be made out.

As the observed figures stand they represent a coupling series in which the gametic ratio (in Bateson's sense) is approximately 240 : 1. If the present supposition is correct we might reasonably expect that some non-black pubescent individuals should appear in the 465 plants. Their absence is probably due to a chance fluctuation. If we may assume that one such individual is to be expected in 465, this will make a total of three crossover plants and the gametic ratio would be approximately 150:1. This means that instead of appearing in equal numbers the different classes of gametes will be formed in the ratio 150 black, pubescent:1 black, non-pubescent:1 non-black, pubescent:150 non-black, non-pubescent.

In regard to the gene for pubescence on the back of the upper grains it will be remembered that the absence of pubescence in this case is dominant over its presence. In the F_2 generation there are 378 plants without pubescence (smooth) to 87 which are pubescent on the upper grain. The ratio here is not 3 to 1, but 4 to 1. Likewise the relation between this gene and the gene for pubescence on the back of the lower grain gives a 9:3:4 ratio. No individuals occur which are smooth on the lower grain and pubescent on the upper. Apparently the gene for pubescence on the lower grain acts as a basic pubescence factor in a manner quite similar to the color factor (C) in mice, rabbits, sweet peas and many other organisms. In the absence of the factor for pubescence on the lower grain the factor for pubescence on the upper grain remains inactive.

The fact that this basic pubescence factor is linked with the black color factor disturbs the phenotypic ratio of the non-black plants when

the character pubescence on the back of the upper grain, is correlated with other characters.

Table 3 shows the relation between this character and the type of base on the lower grain. In this table the cultivated and intermediate types of base are grouped together under the term 'cultivated.'

It is seen at once that there is distinct evidence of linkage between these two genes. Since the ratio in the non-black plants is disturbed by interdependence of two genes, it is necessary, in considering the question of linkage, to use the data from black plants only as given in the second line of the table.

Calculating the probable gametic ratio necessary to produce such an F_2 generation (using the black plants only) it is found that this ratio is approximately 65 to 1.

To sum up the main features of the present hypothesis, it is found that the gene for pubescence on the back of the upper grain segregates independently of the gene for pubescence on the back of the lower grain.

TABLE 3
RELATION BETWEEN THE PUBESCENCE ON THE BACK OF THE UPPER GRAIN AND THE CHARACTER OF THE BASE

	CULTIVATED		WILD	
	SMOOTH	PUBESCENT	SMOOTH	PUBESCENT
All plants.....	352	2	27	85
Black plants only.....	257	2	3	85

However, the former gene is unable to produce a pubescence unless the factor for pubescence on the lower grain is present in the same zygote. The gene for pubescence on the back of the lower grain shows partial linkage with the gene for black color. The gametic ratio is apparently about 150 to 1. The gene for pubescence on the back of the upper grain is partially linked with the gene for the wild base. The gametic ratio in this case is approximately 65 to 1. It is very probable that these gametic ratios will be changed somewhat when larger numbers of individuals are available. It is believed that the present assumption represents the essential facts.

The brilliant work of Morgan and his collaborators upon linkage and its relation to the chromosome theory of inheritance makes it exceedingly attractive to point out the possible relation of these genes to the chromosomes. In the first place it has been shown by Nilsson-Ehle (1909) and partly by the present work that the three pairs of color genes segregate independently of each other. It may, therefore, be supposed that

they lie in separate chromosomes. Further the gene for the character of the base of the grain segregates independently of the color genes. It, therefore, probably lies in a fourth chromosome. The seven characters given in table 1 are very closely if not absolutely linked with the character of the base. If these seven characters may be supposed to be due to separate pairs of genes these must lie in this fourth chromosome.

Still a ninth pair of genes is located in this fourth chromosome, viz., that for smoothness (lack of pubescence) on the back of the upper grain. This gene is apparently located at a slight distance from the group discussed above since it shows about 1.5% of crossovers with the members of that group.

The gene for pubescence on the back of the lower grain is linked with the gene for black color and is, therefore, to be regarded as located in the same chromosome. The per cent of crossovers between these two genes is probably less than 0.7%.

¹ This is an abstract of paper No. 95 from the Biological Laboratory of the Maine Agricultural Experiment Station. The complete paper is now in press in *Genetics*.

² A spikelet of common oats usually bears two grains. The larger of these is called the "lower" grain and the smaller one the "upper" grain. The upper grain is articulated with the lower by means of a short pedicel.

A COMPARISON OF THE RATES OF REGENERATION FROM OLD AND FROM NEW TISSUE

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In determining the factors of regeneration one of the questions that arises is the extent to which rate of growth of the new organ is controlled by the character of the cells at the cut surface. Is regeneration wholly a matter determined by the characteristics of the local cells or is the process under more central control? If the former is true, change in the condition of the cells near the cut surface should modify the rate of regeneration, if the latter, such change does not necessarily mean change in rate.

The present study consists of a comparison of the rate from newly regenerated tissues with that from old tissues. When a portion of the tail of a frog tadpole is removed by a transverse cut there is near the cut surface a considerable degree of reorganization of the cells which are to give rise to the new organ. If, before the completion of regeneration, a second removal is made the regeneration will be from new cells if the second cut is distal to the level of the first and from old cells if it

is proximal to that level. In order to insure equality of level the first cut was made at *A* in the figure for a new tissue basis and at *B* for an old tissue basis, the second regeneration level, in each case coming between *A* and *B*. If rate control is a function merely of the readiness of the cells the second regeneration from the new tissue level should be more rapid than that from the old tissue level.

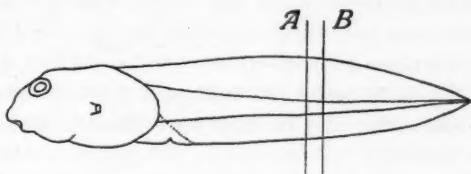


FIG. 1

Three groups of experiments were made on tadpoles of the green frog, *Rana clamitans*. In each it is clear that there is no striking difference between the rates from the two kinds of cells.

In experiment I the average regenerated length in ten individuals at the end of six days is 2.16 mm. from old tissue and 2.15 mm. from new tissue. The removed lengths are not exactly alike in the two cases and it is necessary to make a correction for the difference. It is shown elsewhere that within the limits of the present experiment rate of regeneration is directly proportional to length removed. The specific length regenerated or length per unit of removed length is therefore a constant within these limits. It is therefore fairer to use the specific than the absolute lengths. The specific lengths regenerated in the present experiment at six days are 0.196 for old and 0.204 for new tissue.

In the same experiment at eight days the average lengths are 3.19 mm. from old tissue and 3.12 from new and the specific lengths are respectively 0.303 and 0.310.

These values are given in table 1.

TABLE 1

COMPARISONS OF REGENERATIONS FROM OLD AND NEW TISSUE IN THE TAIL OF THE TADPOLE OF *RANA CLAMITANS*. SERIES 3628-3675

	TOTAL LENGTH	TAIL LENGTH	REMOVED LENGTH	REGENERATION TIME SIX DAYS		REGENERATION TIME EIGHT DAYS	
				Regener-ated length	Specific length regenerated	Regener-ated length	Specific length regenerated
Average from old tissue.	32.9	21.5	11.3	2.16	0.196	3.19	0.303
Average from new tissue.	34.0	22.2	10.7	2.15	0.204	3.12	0.310
Old—ahead.....				0.01		0.07	
New—ahead.....					0.008		0.007
Old—times ahead.....				4	3½	3	3
New—times ahead.....				6	6½	3	3

In experiment II similar data were obtained for four, six, eight, ten, twelve and a half, eighteen and fifty-six days of regeneration. The removed lengths are quite different in the different individuals so that specific lengths alone are valid. Giving the old tissue level first in each case and using only removals of over 4 mm. these values for the seven times are respectively 0.043 and 0.045, 0.135 and 0.143, 0.216 and 0.224, 0.292 and 0.293, 0.331 and 0.337, 0.352 and 0.348, and 0.345 and 0.346. They are given in more detail in table 2.

TABLE 2
COMPARISON OF REGENERATIONS FROM OLD AND NEW TISSUE IN THE TAIL OF THE TAD-
POLE OF RANA CLAMITANS. SERIES 3676-3765

DAYS OF REGENERATION	OLD TISSUE SPECIFIC LENGTH OF REGENERATION	NEW TISSUE SPECIFIC LENGTH OF REGENERATION	OLD AHEAD	NEW AHEAD
4	0.043	0.045		0.002
6	0.135	0.143		0.008
8	0.216	0.224		0.008
10	0.292	0.293		0.001
12½	0.331	0.337		0.006
18	0.352	0.348	0.004	
56	0.345	0.346		0.001
Average.....				0.003

Similar results were obtained when the removed lengths were under 4 mm.

In experiment III completed lengths from old and new tissue are compared in each of the third, fourth and fifth regenerations. It is necessary to point out that in the tadpole tail the completed regeneration is always less in length than the removed tail. The comparison here therefore concerns the degree of replacement of the lost part and not its rate. The average regenerated lengths giving the old tissue levels first are 7.9 mm. and 7.9 mm. for the third, 5.3 and 5.5 for the fourth and 6.6 and 5.9 for the fifth successive regeneration.

The data as a whole show clearly that there is no essential difference between rate of regeneration from new cells and from old cells. There is only a very slight advantage in favor of the new cells while a striking one would be expected if rate were largely determined by local cell characteristics. Rate of regeneration seems therefore to be under central control. This conclusion is in agreement with the results of experiments on other factors.

The full data will be published in the *University of Illinois Biological Monographs*.

THE EFFECT OF SUCCESSIVE REMOVAL UPON THE RATE OF REGENERATION

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One of the most interesting facts in connection with regeneration is the ability to replace a part after repeated removal. Former studies by the writer show that as a rule the rate of regeneration following a removal is no greater than that following second and later removals if the effect of age is eliminated. Where a difference exists it is in favor of the later regeneration.

The matter is of very great interest in connection with general problems of development and particularly in connection with the question as to the existence or non-existence of a necessary limit to the amount of living substance that a single individual may produce during its life cycle. Does the production of a group of tissues use up a part of a certain store of developmental energy possessed by the individual or is this store inexhaustible or perchance even increased by exercise of the function? These questions warrant more extended study especially in view of the additional analysis that has been made of other factors controlling the rate of regeneration. The new data support the conclusion previously reached and make possible a further analysis of the character of the difference between successive regenerations.

In making a comparison of successive regenerations a method must be devised for eliminating the effect of age. If the rate of a second regeneration is compared with that of a first regeneration in the same individual any difference that is made out may be due not to the pure effect of successive injury but to the effect of difference in age.

The method pursued in the present experiments consists in the initial removal of a portion of the tail in one-half of a set of Amphibian larvae of equal age. When regeneration has proceeded for several days there is a second removal of the part accompanied by a first removal in the half of the set that had not previously been operated upon. The second regeneration that ensues in one-half of the set may be compared directly with the first regeneration in the other half. There is no difference in age.

In experiment I approximately one-half of the tail was removed in tadpoles of the green frog, *Rana clamitans*. At six days the average first regeneration length is 2.01 mm. and the average second regeneration length 2.18 mm. The first exceeds the second in five sets and the

second exceeds the first in six. The corresponding specific lengths or lengths regenerated per unit of removed length are 0.194 and 0.205. The first regeneration exceeds the second in two sets, the second exceeds the first in five and one is tied. The second regeneration has the advantage in all the comparisons.

At eight days the average first regeneration length is 3.06 mm. and the second 3.42 mm. The first exceeds the second in three sets and the second exceeds the first in seven. The corresponding average specific lengths are 0.298 and 0.323. The first regeneration exceeds the second in four sets and the second exceeds the first in six. The second regeneration has the advantage in all the comparisons.

This advantage of the second regeneration over the first in experiment I holds true of second regenerations from both old and new tissue levels.

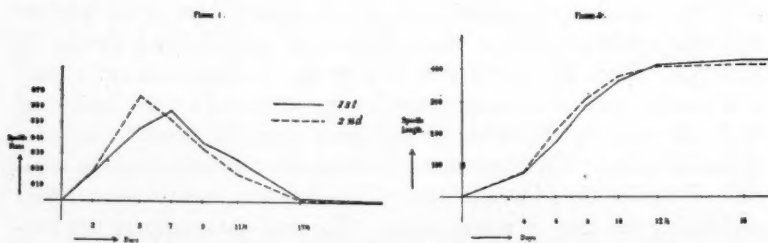


FIG. 1. CHANGE IN SPECIFIC RATE OF REGENERATION DURING THE REGENERATION PERIOD FOR BOTH FIRST AND SECOND REGENERATIONS. TADPOLE TAIL OF RANA CLAMITANS. UNBROKEN LINE = FIRST REGENERATION. BROKEN LINE = SECOND REGENERATION.

FIG. 2. SPECIFIC REGENERATED LENGTHS DURING THE REGENERATION PERIOD FOR BOTH FIRST AND SECOND REGENERATIONS. TADPOLE TAIL OF RANA CLAMITANS. UNBROKEN LINE = FIRST REGENERATION. BROKEN LINE = SECOND REGENERATION.

In experiment II, also with *Rana clamitans*, operations were made at the $\frac{1}{5}$, $\frac{1}{3}$, $\frac{1}{2}$ and $\frac{2}{3}$ levels in a sufficient number of individuals to yield valid data. Regeneration measurements were made at each of these levels 4, 6, 8, 10, $12\frac{1}{2}$, 18 and 56 days after the operations. The second regeneration at these levels is ahead of the first until about the twelfth day after which the first regeneration catches up. The maximum rate for both regenerations is reached before this time, and earlier for the second than for the first regeneration. The relation between the rates is given in figure 1 and between the total regenerated lengths in figure 2.

In experiment III two-thirds of the tail was removed in larvae of the salamander, *Amblystoma punctatum*. A comparison of the first, second and third regenerations was made at 2, 4, 6, 8, 10 and 14 days. At two days the first, second and third regenerations average respec-

tively 0.22, 0.25 and 0.26 mm. The corresponding values at four days are 0.66, 0.75 and 1.00; at six days 1.36, 1.40 and 1.36; at eight days 2.18, 2.68 and 2.68; at ten days 3.55, 3.82 and 4.20; at fourteen days 5.34, 6.12 and 6.08. The advantage is in favor of the second and third regenerations as opposed to the first and of the third as opposed to the second. Individual comparisons at each of the different times show similar results.

The evidence as a whole shows clearly that when the age factor is eliminated there is no decrease in rate of regeneration with successive removal. On the contrary the second regeneration is more rapid than the first up to the period of maximum rate. The second regeneration however passes its maximum sooner than does the first and after the tenth day the latter therefore catches up in total amount regenerated. There is no striking difference between the second and the third regenerations but in each comparison the third has a slight advantage.

When successive regenerations within single individuals are compared there is a progressive decrease in rate and it is obvious that this is due to age.

The possibility has suggested itself that the second regeneration starts out at a more rapid rate than the first because the cells at the cut surface were undergoing regenerative changes at the time of the new operation and can therefore start the process much faster than can the old cells at the first surface of regeneration. Following a first removal there is a considerable degree of reorganization of the cells at the cut surface, accompanied by active migration. During this period which in *Rana clamitans* lasts two or three days there is little or no mitotic cell division. Then follows a division period which reaches its maximum at seven to ten days. Its decline is associated with the oncoming of tissue differentiation.

A special study has been made of the relative rates of second regeneration from old cells following a cut inside of the first removal level and from new cells following a cut outside of the first level. This comparison shows only a very slight difference in favor of the new cells and this is largely confined to the early stages, the period of cell migration.

The period of increase in rate is the period of active cell multiplication and the decline in rate is associated with cell differentiation. The second regeneration therefore reaches the period of differentiation slightly in advance of the first regeneration.

Apart from the slowing due to age there is no indication of a limitation of the amount of new material that may be produced by regeneration. The actual limitation comes not from the using up of regenera-

tive or developmental energy or of 'determiners' by repeated regeneration but from changes in the non-regenerating part associated with age. In another place there is a discussion of the possibility that there may be an effect upon the rate of developmental processes in the organism as a whole due to continued regeneration of a part. This is studied particularly in connection with the effect of regeneration upon rate of metamorphosis in Amphibia.

Regeneration studies in general and those on successive regeneration in particular make it improbable that there is a definite number of cell regenerations between the fertilized egg and the end product, the differentiated cell. The possibility that certain cells may remain in an early cell generation can not be wholly excluded as an explanation of at least part of first regeneration phenomena. Under suitable stimulation such cells may be postulated to take up development where it has left off. The definite descriptions of de-differentiations of cells as well as other facts of regeneration argue against this conclusion. The view that there can be no such definite number of cell generations is strengthened by the facts of successive regeneration. It does not seem probable that embryonic cells of an early cell generation can be held in reserve through repeated regenerations.

The explanation of regeneration by the theory of duplicate sets of determiners meets difficulties in undiminished successive regenerations. The greater the number of repeated regenerations the greater the difficulties of explanation on this basis. Of course the difficulty does not hold for the hypothesis that every cell or nearly every cell contains a full set of determiners.

The earlier appearance of the maximum rate in the second than in the first regeneration may be due to the more rapid progress of the cells in the early cell migration period alone or it may be due to the acceleration of the whole developmental cycle.

The full data will be published in the *University of Illinois Biological Monographs*.

THE GEOLOGIC RÔLE OF PHOSPHORUS

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Phosphorus appears in nature in many forms and in many situations. Its numerous transformations, however, follow an orderly sequence. In a broad way, the changes form a cycle but since the path of change

divides here and there, the element really progresses through a series of subordinate cycles all having a common beginning and capable of being brought eventually to a common end.

Omitting the rare meteorites, we find the primary source of phosphorus in magma (molten lava). Almost all magmatic rocks, whether they solidify in the interior of the earth or are poured out upon its surface, contain this element. According to Clarke,¹ the average igneous rock of the world contains 0.29% of P_2O_5 . The proportion is somewhat greater in the basic rocks, such as gabbro and the peridotites; and in the peripheral portions of certain magnetite ore bodies, which are believed to be merely ultrabasic segregations from a less basic magma, the quantity of P_2O_5 may exceed 10%. In these rocks the phosphorus almost invariably appears in the form of the mineral apatite, a compound of tricalcium phosphate with calcium fluoride or chloride.

The hot solutions and vapors emitted by subterranean bodies of magma, especially during the progress of crystallization, permeate the adjacent rocks, and, through the crystallization of their constituents upon the walls of fissures, are believed to form the veins known as 'pegmatites.' In rare instances pegmatites contain noteworthy quantities of apatite—generally in large crystals. Some of the Norwegian apatite deposits are probably of this origin.

There is another type of phosphatic veins which is even rarer than the pegmatitic variety, although locally in central Spain there are important deposits of this kind. These are the fibrous veins consisting not of apatite, but of the minerals staffelite or dahllite—hydrous calcium carbo-phosphates² containing about 38% of P_2O_5 . These veins traverse quartzite, slate and limestone, but have a suggestive association with intrusions of granite. While their origin is not known, it may be suggested that they will eventually prove to have crystallized from magmatic solutions at a considerable distance from the parent intrusion and at a comparatively low temperature. Certain even rarer primary deposits containing phosphorus minerals may be neglected in this brief sketch.

At and near the surface of the earth, and under favorable climatic conditions, rocks of all kinds are subject to chemical decomposition. One of the chief agents of this process is ground water containing carbonic acid and other solvent substances. In this weak solution apatite and the hydrous phosphates such as dahllite dissolve somewhat readily, as compared with most other common minerals, although much less rapidly than calcite ($CaCO_3$).

The dissolved portion circulates through the rocks and is disposed of

in several ways. Much of it is absorbed by plants and thus vicariously by animals, but returns again to the soil after the death of the organism, if not before. A very large part either immediately or eventually joins the streams and finds its way to the ocean, suffering on the way certain minor losses which may be passed over here.

Of the vast quantities of dissolved mineral matter delivered to the ocean annually by streams, it is estimated that nearly $\frac{1}{2}$ of 1% (0.45%) consists of phosphoric acid. Using the best available figures for the amount of water reaching the ocean, we may calculate that if the phosphatic material in the form of tricalcium phosphate were loaded into standard railroad cars it would fill a train stretching continuously from New York to Seattle and would be from 7 to 12 times as great as the world's total production of phosphate rock in 1911. Nevertheless so great is the volume of the oceans, and so vast the area of their floors, that if all of this material were converted into phosphatic minerals and deposited uniformly over the bottom of the sea, it would serve to form annually a layer less than $\frac{1}{8}$ mm. thick. Of the phosphorus poured into the sea, so large a proportion is utilized by living things that the net working balance dissolved in oceanic water at present averages less than 0.005%, expressed as P_2O_5 , or about $\frac{1}{6}$ % of the salts dissolved. This seemingly represents the most diffuse state reached by phosphorus in the course of its complex migrations. Its subsequent transformations, now to be described, generally tend toward ever greater concentration almost until the cycle is closed upon itself.

Soluble phosphates are absorbed by the myriads of oceanic plants. In some measure they become chemically linked in organic compounds but for the most part they probably remain as salts or ions. Living diatoms and other algae contain in both of these states $\frac{1}{16}$ to $\frac{2}{16}$ % of P_2O_5 . These organic substances containing phosphorus are devoured by an all but infinite variety of aquatic animals, each of which is in its turn liable to a similar fate. This endless process of devouring is recognized even in the ancient Chinese proverb to the effect that "the big fish eat the little fish, and the little fish eat the shrimp, and the shrimps eat the mud." In the individual animal, the phosphorus forms a constituent of its tissues, cells, liquids, and in some groups also its teeth, bones, shells and other hard parts.

There are at least two ways in which the phosphorus may escape from this oceanic cycle. The organisms of the sea may be eaten by land animals, chief of which are the birds, or the phosphorus may be fixed among the solid deposits on the sea bottom and eventually buried beneath the accumulating sediments. The second of these processes will be considered first.

At somewhat rare intervals, marine animals are killed in enormous numbers by sudden changes in temperature, by volcanic eruptions, submarine earthquakes, and other catastrophes. The carcasses of such animals generally float; but some may come to rest upon the sea bottom. In either event the omnipresent forces of decay rapidly convert the carcasses to soluble form and thus return their constituents to the oceanic solution before they are deeply buried. It is conceivable that, under the most favorable circumstances, a layer of bones and teeth might be left on the sea floor; but at best the reality of fixation in this manner is doubtful.

As an incident to the normal life of vast numbers of organisms both on the sea bottom and in its upper waters, shells and pellets of solid excrement are incessantly falling to the sea bottom. Dredging operations have shown that in many places the latter material forms an appreciable part of the bottom sediments³ and in a few places the sediment has been found to consist almost entirely of such pellets, especially those of holothurians, marine worms, and echinoids. Under normal conditions, this material is devoured by the various scavengers of the sea bottom, and any portion that may be left is fermented by bacteria. Insofar as this action prevails, phosphorus cannot well become a solid part of the sediment deposited on the sea floor.

Under conditions probably anaërobic but not yet well understood, a quite different process may operate. The organic refuse fermented by bacteria in the absence of free oxygen yields such compounds as hydrocarbons, carbon dioxide, hydrogen sulphide and ammonia. Under favorable chemical conditions the phosphoric acid also liberated will react with various substances, particularly lime salts. With the latter it produces the mineral collophanite, a hydrous calcium carbo-phosphate.⁴ Where calcareous shells lie on the sea bottom, they become phosphatized. Even organic matter such as excretory pellets, pieces of wood, and other non-calcareous materials, are altered in this way. Bones which initially contained about 58% calcium phosphate are still further phosphatized until that percentage rises to 85 or more. In addition, the collophanite forms little round grains resembling the oolitic grains common in certain limestones. It is also deposited as a cement between the particles of all kinds, thus producing hard nodules or even continuous solid beds of phosphate rock. At the same time, probably by the influence of carbonic acid evolved during the decay of the organic matter, lime carbonate is dissolved. Many facts indicate that in these situations only the phosphatic mineral is stable, even though lime

carbonate shells may at the time be falling from the surface to the bottom of the sea. In such a phosphatic deposit the content of phosphorus pentoxide may range from less than one to at least 36%. Sediments of this type, subsequently lifted above the sea, have become the rare but locally voluminous source of our most important commercial phosphates, or have served as a necessary antecedent for the later formation of such deposits.

Reference has already been made to the fact that through the agency of birds and other animals of the land, phosphorus may escape from the cycle of changes in the ocean. Upon islands where they are out of reach of predaceous mammals, sea-birds congregate in extraordinary numbers, and the amount of excrement annually deposited by them on the surface of these islands is large.

In moist regions bacterial fermentation decomposes this material and the soluble resultants are removed by rain water so rapidly that little residue is left. On those islands, however, which are situated in the dry trade-wind belts, this process is almost inoperative, and hence the guano accumulates from year to year. The dry guano—before subsequent alterations have taken place—contains as much as 28% P_2O_5 , plus organic matter. During moist seasons, transient though they may be, the guano is subject to fermentation by microorganisms such as the bacteria, with the result that the nitrogenous matter is largely converted into ammonia, and is lost. The occasional rains dissolve out some of the soluble phosphates and most of the nitrates, leaving a residue of solid 'stone guano' containing as much as 39% of P_2O_5 , largely in the form of hydrous acid and basic calcium phosphates.

The solutions derived from the guano above sink downward through the underlying rocks, and produce characteristic alterations in them. If the subjacent terrane be limestone, it is slowly converted into a mass of calcium phosphate, in which the minerals colophonite and stafelite (?) are the characteristic forms. Observations on the islands in the Indian Ocean indicate that coralline limestone has been changed in recent times at the rate of 2 or 3 feet in twenty years.⁵ In the laboratory, a coral skeleton became 60% phosphatized in only two months.⁶ On volcanic cones, even such refractory igneous rocks as andesite have been converted superficially into a mass of aluminum and iron phosphates.

These processes of alteration near the surface of the earth affect not only the guano deposits, but also the marine sediments which contain phosphatic minerals. Some of the Cretaceous chalk deposits of Belgium, which it appears originally contained from 1 to 4% of P_2O_5 , have been converted by the differential leaching of lime-carbonate by

carbonated waters into much thinner beds, in which the proportion of P_2O_5 has arisen to more than 30%. As in the case of guano, more or less of the lime phosphate is dissolved along with the lime carbonate, and sinking down through subjacent limestones, converts them into secondary beds of phosphate rock. Our important Florida deposits (the hard rock variety) are believed by Sellards⁷ to have originated in this manner. Other examples of the same type are probably to be found in the limestone plateau of southern France, some of the phosphates of central Tennessee, and many other regions.

Phosphatic deposits of any of the types already described may be buried to great depths and there be subjected not only to great vertical pressures but to the even more intense horizontal strains that accompany mountain folding. In harmony with the well established principle that most rocks tend to recrystallize under these conditions, the phosphatic rocks are probably reorganized. The hydrous minerals characteristic of the surface must become dehydrated, and there is also a tendency for carbonic acid to be driven off. As a result, beds which originally consisted of the hydrous carbo-phosphates—collophanite, dahllite and others—are believed to pass over into pure apatite, in which the proportion of P_2O_5 may rise to nearly 43%—the maximum attainable. Although none of the known apatitic deposits have thus far been proved to have originated in this way, it is more than probable that illustrations of this type exist. It has been suggested that the rich apatitic beds associated with the Grenville marbles and gneisses near Ottawa, Canada, are really the highly anamorphosed representatives of phosphatic sediments once deposited on the surface of the land or sea bottom.

There is no obvious reason why deeply buried layers of phosphate rock invaded by fluid lava from below should not be dissolved by the latter, diffused through its mass, and eventually crystallize as apatite disseminated through the resulting igneous rock. Insofar as this occurs it closes the cycle, for the phosphorus is thus brought back to its original condition, albeit after untold ages of migration and transformation in the surficial portion of the earth.

¹ Clarke, F. W., *Data of Geochemistry, Bull. U. S. Geol. Survey*, No. 616, p. 27 (1916).

² According to A. Lacroix, *Mineralogie de la France*, v. 4, pp. 555 et seq.

³ Murray, Sir. J., and Philippi, E., *Wissenschaft. Ergeb. der Deutschen Tiefsee Exped.*, Bd. X, Lf. 4, (1905) (Carl Chun, editor).

⁴ Lacroix, A., *Mineralogie de la France*, v. 4.

⁵ Willis, J. L., *Ottawa Naturalist*, 6, 18 (1892).

⁶ Collet, L. W., *Proc. R. Soc. Edinburgh* 25: 882.

⁷ Sellards, E. H., *Florida Geol. Survey, 5th Ann. Rept.*, pp. 37-66 (1913).

DOMINANTLY FLUVIATILE ORIGIN UNDER SEASONAL
RAINFALL OF THE OLD RED SANDSTONE

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The Devonian system is represented in the British Isles by a series of rocks many thousands of feet in thickness, none of which, except in the south of England, hold marine fossils. Red sandstones constitute the predominant exposures, the colors ranging from light red to deep chocolate-brown, but in places are also found sandstones and shales of green, gray, or yellow colors. Besides the sandstone, the system includes much shale and conglomerate, the latter in places consisting of large-sized and subangular débris. Much volcanic material is intermixed in certain localities. This system of rocks, so distinct from the marine formations, has been familiarly known since the days of Hugh Miller as the Old Red Sandstone.

The sediments are mostly barren of organic remains, but at certain horizons many fossils have been found,—plant fragments, estheria, scorpions, myriopods, eurypterids, ostracoderms, and fishes. Several distinct faunas are found, representing successive epochs. These fossil faunas contain the oldest known ganoid fishes and the oldest well preserved representatives of those primitive and spinose sharks,—the acanthodeans. Ostracoderms are well represented also. In contrast to this abundant preservation of chordates in certain horizons of the Old Red Sandstone, the rocks of earlier geologic periods show only rare and usually fragmentary remains belonging to this phylum.

Our own ancestral line is regarded as having ascended through elasmobranchs and crossopterygian ganoids. These groups evidently flourished at the time of the Devonian period within the environment under which the sediments of the Old Red Sandstone were laid down. If, then, we can determine the conditions of origin of those sediments we shall restore by so doing the life surroundings of the primitive ancestral vertebrates; life surroundings which were related to their passage from the realm of the waters to that of the land and air.

Godwin-Austen, noting the distinctness of the Old Red Sandstone formations from the typical marine Devonian, was led to a view in 1855, previously maintained by Dr. John Fleming, that the sediments were laid down in great freshwater lakes or inland seas. This interpretation rapidly supplanted the older view advocated by Hugh Miller, that the Old Red Sandstone was of marine origin. This lacustrine interpreta-

tion prevails in British opinion to the present day, though it is true that Macnair and Reid¹ reverted in 1896 to the hypothesis of marine origin, and Goodchild in 1904,² pressing in the other direction, urged "that the whole of this vast formation was accumulated under continental conditions, partly in large inland lakes, partly as torrential deposits, partly as old desert sands, and partly as the result of extensive volcanic action." In 1908 Walther published a volume which consisted of a general review of historical geology. In the section touching on the Old Red Sandstone, he held that the lakes of the British geologists were in reality desert basins which "possessed a hot desert climate whose dry periods were broken only seldom by the downpour of thunder storms."³

In other places Kayser and Walther have expressed the view that the Old Red Sandstones were deposited in lagoons not far from the sea, the water being thought of as occasionally replenished by the sea and the deposition as taking place in lagoons and as dunes on their margins.

Thus we see that a great variety of conclusions, amounting in fact to flat contradictions, have been expressed and are still entertained by geologists in regard to the nature of the habitat of the early vertebrate faunas whose remains are found in the formations of the Old Red Sandstone. Yet this is to the geologist and biologist a most important problem, especially as it may be shown that the conditions of the environment held important causal relations to the rise of amphibians.

The differences in conclusions are not due to differences of opinion in regard to the actual facts of stratigraphy, but to radical differences in the interpretation of those facts. At the present stage of investigation it is of the first importance therefore to determine the criteria for interpretation and their degree of validity. It is that subject especially to which the writer has given attention in previous investigations. The present conclusions rest therefore upon the following papers.

In November, 1906, the writer, introduced by Professor Davis, gave a paper before the National Academy of Sciences entitled 'Continental Sedimentation with Applications to Geological Climates and Geography.' The articles on this general subject were published *in extenso* in the *Journal of Geology* in 1906 and 1908.⁴ In 1913 and 1914 articles were published in the *American Journal of Science* on the formations in the eastern United States which correspond to the Old Red Sandstone system of the British Isles.⁵ In the present article, therefore, the establishment of the criteria on which the conclusions rest may be omitted and the resulting interpretation directly given.⁶

This interpretation leads to the conclusion that the deposits which make up the Old Red Sandstone, although they undoubtedly contain

lacustrine beds and other beds laid down in shifting, shallow, and variable bodies of water, are dominantly fluvial in origin; laid down over river flood plains by streams in times of flood, exposed to air in times of drought. They record in this way the existence of an alternation of seasons of rainfall and drought—a climate with an arid season, but not an arid climate. This type of climate is best defined as semi-arid, and is existent over broad areas at present, especially in much of the torrid zone. Such a climate is to be sharply distinguished in thought, on the one hand, from that of a typically humid character, such as now prevails in northwestern Europe and northeastern North America; and, on the other hand, from truly desert climates, such as prevail in central Asia or northern Africa. The conclusion as to dominantly fluvial origin,—similar to the mode of origin of the sediments now accumulating within the Great Valley of California, or on the Plains of Mesopotamia, is also to be sharply distinguished from the conception of great and permanent lakes, as well as from the opposite conception of torrential and eolian conditions in desert basins. Thus the present interpretation is distinctly different, both in regard to climatic and physiographic conditions of origin, from either the prevailing British or the German conceptions, but approaches nearest to that given by Goodchild.

The character of this interpretation may be called American, for in its main lines the writer does not stand alone. W. M. Davis, Hatcher, and others have shown the general importance of flood plain deposition. Especially may be mentioned the work of Grabau who has independently reached similar conclusions in regard to the importance in certain Paleozoic formations of fluvial deposition. He has studied the Old Red Sandstone in the field and, though he has not published on that subject, has publicly stated that his conclusions are the same as those here expressed. More recently Schuchert has reviewed the evidence and expresses similar conclusions, though the part played by rivers as distinct from lakes is not so sharply differentiated as in the papers of Grabau and the writer.⁷

In closing we may draw a picture of the geography of Great Britain in Lower Devonian times. The region was then a part of a continent which extended an unknown distance northward and westward. Beyond the northwestern side of Great Britain extended a mountain system. The region of Great Britain was, in this newer interpretation, made up of a sequence of river basins separated by minor ranges of mountains, the whole marginal to the greater mountain system. Sediment was brought into these basins by rivers from the bordering uplands and from the more distant regions to the northwest. The excess

beyond what was laid down by the rivers in time of flood to maintain their grade across the sinking basins was carried through to the shallow sea which lay on the surface of the continent to the southwest. The relations were somewhat similar to those which now prevail between the ranges of the North American Cordillera and the Tertiary basins which lay between them and especially on the west between the Sierra Cascade chains and the Coast Ranges. The Great Valley of California may therefore in the present epoch, both in physiography and in climate be cited as a striking illustration of the nature of the Old Red Sandstone basins.

¹ Macnair and Reid, *Geol. Mag. Decade IV*, 3, 106-116, 217-221 (1896).

² Goodchild, J. G., The Older Deutozoic Rocks of North Britain, *Geol. Mag. Decade V*, 1, 591-602 (1904).

³ Walther, J., *Geschichte der Erde und des Lebens*, 259 (1908).

⁴ Barrell, J., Relative Geological Importance of Continental, Littoral, and Marine Sedimentation, *J. Geol.*, 14, 316-356, 430-457, 524-568 (1906); Relations Between Climate and Terrestrial Deposits, *Ibid.*, 16, 159-190, 255-295, 363-384 (1908).

⁵ Barrell, J., The Upper Devonian Delta of the Appalachian Geosyncline, *Amer. J. Sci.*, 36, 429-472 (1913), 37, 87-109, 225-253 (1914).

⁶ This paper was given in brief form at the meeting of the American Society of Vertebrate Paleontology at New Haven, Conn., on December 26, 1907 [Loomis, F. B., Report of the Secretary, The American Society of Vertebrate Paleontology, *Science*, 27, 254 (1908)], and more fully at the meeting of the Geological Society of America at Washington, December 28, 1915. It will be published in full in the *Bulletin of the Geological Society of America* in 1916. The present paper is a digest and its chief importance is because of its bearing on the environment of early vertebrates. In that way it is introductory to a paper on the Influence of Silurian-Devonian Climates on the Rise of Air-breathing Vertebrates which will follow in these PROCEEDINGS.

⁷ Pirsson-Schuchert, *Text Book of Geology*, Part II, *Historical Geology*, by C. Schuchert, 714-721 (1915).

THE INFLUENCE OF SILURIAN-DEVONIAN CLIMATES ON THE RISE OF AIR-BREATHING VERTEBRATES

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The problems of organic evolution have many aspects and ramify into many fields of science. The subject was at first embraced chiefly in the domain of the old time naturalist—zoologist or botanist. But the problems of variation and heredity have passed into the hands of the experimental evolutionist; and there are other problems whose answers are found in the geologic record—but these are of two rather opposite aspects. On the one hand, the paleontologist specializes particularly

on the organic features, the successions and relations of fossil faunas or floras. On the other hand, it is the work of physical and historical geology to restore the ancient environments. The relations of the environments to the biotas is a field wherein physical geology and paleontology meet, to give a better understanding of the underlying physical surroundings associated with organic response and progress. It is from the standpoint of physical and historical geology, rather than from that of paleontology that the present study is made.

In this subject are two major problems—first as to the environment in which fishes developed; second, the changes in the environment and the associated organic responses which brought forth amphibians from fishes. It is the solution of the second problem which is here especially sought,¹ but it involves a statement of the evidence in regard to the first.

The question in regard to the origin of fishes is as to whether they developed first in the sea and later invaded the land waters, as has been generally assumed, or whether their expansion was in the opposite direction—from rivers to embayed waters and thence finally to the sea. Chamberlin appears to have been the first to have seriously suggested that the latter may have been the real direction of their emigration.² He pointed out that the fishes appeared as fossils only in the embayed waters until they had attained such dominance that they spread into the truly oceanic realm. Their body form, furthermore, Chamberlin notes, is peculiarly adapted to the stemming of currents and suggests an initial adaptation to rivers.

The evidence for this hypothesis of the continental origin of fishes has been examined by the writer, by taking up the earliest faunas and studying the mode of origin of the associated sediments. The results strongly support Chamberlin's position. The exclusively marine habitats of the lowest remaining chordates, constitute really negative evidence on the subject, for these forms are far removed from fishes, and they leave no fossil record. The original habitats may have been far wider and the progressive forms may have lived a freer life than is shown by these retrogressive and more or less aberrant relics. The positive evidence given by the early fish fossils is more definite and conclusive. A review of this is as follows:

The earliest known ostracoderm remains were found by Walcott in 1891 near Canyon City, Colorado, in a horizon belonging to the base of the Middle Ordovician, in sandstones *which rest upon the Pre-Cambrian*.³ These sandstones are marginal marine deposits, holding species

of *Lingula*, *Orthoceras*, and *Beyrichia*. With these are found abundantly at several levels waterworn scales and plates of ostracoderm fishes. The sandstones are succeeded by marine limestones of Trenton age, but in the limestones, although marine fossils are abundant, the fish remains are absent. If we seek to interpret the origin of these sandstones and their fish remains, it is to be noted that the thickness, 86 feet, is large to have been formed by wave action on a nearly base leveled land. But rivers bring most of the sediment to the sea which is laid down as sandstone, and it is probable that most of this sand was of river derivation. The waterworn character of the fish remains indicates a degree of transportation which the other fossils do not show, and suggests driftage into the region of burial. The absence of all fish remains in both Ordovician and Silurian deposits of solely marine nature strengthens the view that these rare and fragmentary finds were floated into the marginal waters from the rivers.

In mid Silurian red shales of Pennsylvania and in the Upper Silurian Ludlow rocks of Great Britain have been found the next clear appearance of fish remains, mostly of ostracoderms, in associations which seem to indicate at this geologic stage a life of these bottom dwellers not exclusively in the rivers but also probably in protected and brackish embayments of the sea. More clearly, however, they did not yet live in the open sea.

The first true fish fauna, as represented by sharks, in better preservation and considerable variety, is found in the Lower Old Red Sandstones of the Caledonian basin. These are lowest Devonian in age. But the sediments are of a different nature from the marine or brackish water deposits of the Ordovician and Silurian which held the earlier fossils. Viewed in the light of the modern knowledge of the nature of alluvial deposits, the sediments of the Old Red Sandstone are interpreted as having accumulated as river deposits on flood plains or in shallow lakes of an interior basin, lakes subject to marked shrinkage in area during the dry season.

The ganoid fishes appear for the first time and in force in the Middle Old Red Sandstone formations of the Orcadian basin of northeastern Scotland, twenty species belonging to seven genera being known from that basin. Dipnoans also appear at the same time. The enveloping deposits are regarded as Lower Devonian in age, though younger than the deposits of the Caledonian basin.

In contrast to this land water record of the lowest Devonian, the sharks are not found in declaredly marine rocks until at least the Middle

Devonian, and they did not dominate the sea in such exclusive fashion as they dominated the continental deposits of the Lower Devonian until the opening of the Mississippian (Lower Carboniferous) period. In contrast also to the abundant ganoid fauna in the continental waters, only a single species of ganoid is found in the marine Ulsterian (Middle Devonian) rocks of the interior of North America, and they have but scanty representation in the seas until the Mesozoic era. This record appears to show conclusively that the center of piscine evolution was within the land waters, and that the ganoids represented a closer adjustment to that environment than did the sharks.

This brings us to the second problem, the relation of environment to the origin of the amphibians. The nature of the sediments shows that through Silurian and Devonian times the climates, although subject to variation, tended to be warm and semi-arid, that is, marked by a pronounced alternation of wet and dry seasons. In the middle Silurian in fact a high degree of aridity existed in certain regions. The initial development of ganoids, distinguished in their organization from sharks by their capacity to supplement the use of water in respiration by the direct use of air in an air bladder, probably goes back to this Silurian epoch of aridity; since in the Middle Old Red Sandstone stage they are already well differentiated and expand in numerous species through the fresh waters. We must look to the previous period therefore for their origin. During the Upper Devonian the climate became more markedly semi-arid than in the Lower Devonian. Then the traces of sharks disappear completely from the fresh waters, but dipnoans and ganoids continue to exist. This migration of the sharks in habitat is logically to be correlated with the fact that elasmobranchs have no air bladder, not even in rudimentary or vestigial form, whereas the other two orders are so provided. It is notable that the few living species of dipnoans, or lung fishes, are restricted at the present time to tropical regions whose flowing waters are restricted to a wet season, and show such marked adaptations for surviving through seasons of drought that in those environments they possess a permanent advantage over other fishes.

The fossils of fishes in the Old Red Sandstone are apt to be crowded into occasional layers and are associated with bitumen, indicating in those layers an unusual amount of organic matter buried without being exposed to atmospheric oxygen. Judged by the environment, they appear to have died in shoals owing to crowding into the foul waters of pools shrinking in the dry seasons. The seasons of drought formed the

critical factor in their environment. No traces of amphibians are found, though by the law of anticipation they must have been in existence in Upper Old Red Sandstone times; since they are typically developed at the opening of the following period. The amphibians seem therefore to have originated in more limited regions where fishes could not survive and the waters were not sufficiently permanent for the preservation of their remains.

The preceding arguments have been drawn from the geologic record. Let us now turn to another record,—that embalmed in the nature of living vertebrates, especially lung fishes and amphibians; for they preserve practically unaltered a stage of respiratory and circulatory evolution which had been attained in the Devonian. We may find by examining their organic nature whether the development of lungs was a spontaneous, internally directed organic advance, giving increased activity and efficiency, or whether at first it was a mere makeshift response to the pressure of adverse external conditions.

The air-bladder of ganoids and higher fishes is related to the intestinal region, not the pharyngeal region, as is shown both by its direct connection with the oesophagus in ganoids and in the embryos of other fishes. The blood system shows the same, the dipnoans, ganoids and amphibians having the air-bladder or lungs supplied with blood from a *branch of the fourth efferent gill artery*. In each round of the circulation only a portion of the blood is passed through the primitive lungs. The efficiency of this is so limited that the higher fishes living in well-aerated waters, though descendents of ganoids, have turned a primitive breathing organ to other uses and have reverted wholly to the use of gills. The function of the air-bladder was, then, to tide over periods of partial asphyxiation in foul waters, and seems to have been initially developed from a habit of swallowing air, gasping and finding this mode of relief. If forced to rely wholly upon this, it sufficed merely to keep the fishes alive until a new season of floods should recur, expanding the sphere of action and the supply of food simultaneously with the renewed gill-respiration and increased activity of the inhabitants of the river and playa waters. The use of gills, furthermore, could not become completely eliminated until such great changes had progressed in the heart and circulation inherited from elasmobranchs as are found in modern lung fishes and amphibians. It was this initial inefficiency of air-breathing which seems the strongest proof that it was an adaptation forced by the compulsion of nature, not the expression of a hypothetical innate tendency for advancement in organization. Of course, the or-

ganisms must possess at the same time an instability of germ plasm, permitting variations or mutations to arise. These would under the law of probabilities be more often degenerative than ascensive, but the strenuous environmental conditions cut off unsparingly all but the favored few which showed increased efficiency in meeting the critical factor in the environment. The rising death rate owing to recurrences of seasons of marked aridity was the ultimate cause back of the rise of air-breathing vertebrates. Natural selection, by the survival of the fittest, is shown thus, by matching the advance in life to the necessities of environment, to be the overarching cause which led the vertebrates to the possession of the land, their future theater of high evolution. It is doubtful in view of this conclusion if vertebrates could have attained their present dominance of the land without the driving effect of climatic adversities such as are found in the Devonian.

The biologist who studies variations, mutations, Mendelian factors, hybridization; the paleontologist who studies orthogenetic variations, the budding and expansion of phyla, are looking at the expressions of internal forces. These, however, do not constitute a complete picture of the cause and effects of organic evolution any more than the observer of a running antelope could fully explain its flight as the result of the coördination of nervous and muscular actions on a skeletal framework. He must also take into account the ultimate cause—the carnivore behind, and also the carnivores which pursued its ancestors through millions of years. The ultimate controls of evolutions are found in a study of the geologic record, though the possibilities of evolution must be latent within the organism. Natural selection, although discredited as a cause determining specific variations, appears nevertheless to be a major factor in evolution, the driving cause in association with changes in environment, which has forced the great advances in organic progress.

¹ This paper was given orally by the author before the American Society of Vertebrate Paleontology, December 26, 1907 [Loomis, F. B., *Secretary*, The American Society of Vertebrate Paleontology, *Science*, 27, 254-256 (1908)], and also before the Geological Society of America at Washington, December 28, 1915, and the complete paper will be published in the *Bulletin* of that Society in 1916. Some discussion of the subject has also been given by Professor Schuchert in his recent text on *Historical Geology* (Part II of Pirsson-Schuchert, *Text Book of Geology*).

² Chamberlin, T. C., On the Habitat of the Early Vertebrates, *J. Geol.*, 8, 400-412 (1900).

³ Walcott, C. D., Preliminary Notes on the Discovery of a Vertebrate Fauna in Ordovician Strata, *Bull. Geol. Soc. Amer.*, 3, 153-172 (1892).

DENSITY OF RADIO-LEAD FROM PURE NORWEGIAN
CLEVEITE

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Through the kindness of Prof. Ellen Gleditsch of the University of Kristiania we have been so fortunate as to receive a specimen of lead sulphide from carefully selected Norwegian cleveite. According to Dr. Gleditsch, "The Norwegian uraninites are very old and very unaltered. They are found in well developed crystals and occur in connection with the pegmatite dykes in southeastern Norway." The sample in question occurred in cubic crystals near Langesund.

As Hönigschmid has already pointed out¹ the properties of radio-lead (this name being used provisionally to designate lead produced by radioactive transformations) obtained from pure minerals of this sort are far more interesting and significant than those of lead obtained from ordinary uranium ores, which doubtless contain some admixture of ordinary lead. Hönigschmid has shown that the lead from pure cleveite has an atomic weight as low as 206.06, and our own experience with the sample referred to above essentially confirms this result, as will be shown in another communication. So far as we know, however, the density of lead of this kind has not yet been determined, and accordingly the present paper recounts such a determination, which forms an interesting sequel to the recently published results on the density of Australian radio-lead.²

The purification of the sulphide, which doubtless contained traces of sulphides of other metals was carried out as follows: The specimen was dissolved in nitric acid and crystallized three times with centrifuging as nitrate,—a process which Baxter's experience has shown to be an excellent one for the purification of lead from other metals.³ From this purified nitrate the chloride was precipitated by pure hydrochloric acid, and this salt was crystallized three times. The final crystals, after draining on the centrifuge, were stored in a vacuum desiccator over caustic soda. The chloride thus prepared was used for the determination of the atomic weight, the density being determined in the material saved from the filtrates from that determination. These filtrates contained excess of silver, therefore enough hydrochloric acid was added to bring the concentration of the dissolved chloride ion to 0.01 normal, because at this concentration silver chloride is most nearly insoluble.⁴ When the precipitated silver chloride had settled and had been removed

by filtration through a Gooch-Munroe crucible with platinum mat, the resulting solution was concentrated and crystallized once more as nitrate. The pure crystals were electrolyzed, and the pure radio-lead treated exactly as in the case of the other samples previously described.⁵

As the amount of substance at hand was very small, the work could not be done quite so accurately as before. The density determinations were made in the same pycnometer as before, by the second method described on page 223 of our previous publication, the volume of the pycnometer having been redetermined because its tip had been broken in the meantime. Four identical determinations gave 5.7200 as the weight of water in the pycnometer at 19.94°, weighed in air. Therefore, the volume of the pycnometer was 5.7361 cm.

TABLE I
DENSITY OF LEAD FROM CLEVEITE

OBSERVED WEIGHT	WEIGHT IN VAC. (W)	OBSERVED WEIGHT WATER NOT DISPLACED	CORRESPONDING VOLUME	VOLUME OF PYCNOMETER	VOLUME (V) OF WATER DISPLACED	DENSITY (W/V)
4.4252	4.4250	5.3287	5.3437	5.7361	0.3924	11.277
4.4252	4.4250	5.3286	5.3436	5.7361	0.3925	11.274
4.4252	4.4250	5.3285	5.3435	5.7361	0.3926	11.271
4.4252	4.4250	5.3285	5.3435	5.7361	0.3926	11.271
					Average	11.273

The density of this sample, presumably a nearly pure isotope, is thus 11.273, distinctly less than 11.289, the density of the Australian radio-lead, and still less than the density 11.337 found for ordinary lead. The decrease is almost exactly proportional to the decrease of the atomic weight in these samples; for the atomic weight of the Australian lead was about 206.35, and that of this sample 206.085. Thus the atomic volume of the isotope, 18.281 (equal to 206.08/11.273), is almost identical with that of pure lead, as indicated by our previous experiments. Thus 18.281 is essentially equal, within the limit of error of experiment, to the value 18.277, found for ordinary lead, and to the value 18.279, found for Australian radio-lead. It is interesting to note that Australian radio-lead would be essentially duplicated as to these properties by a mixture consisting of three parts of pure isotope to one of ordinary lead.

¹ Hönigschmid, *Sitzungsber. Wiener Akad.*, 123, II a, 20 (1914).

² Richards and Wadsworth, *J. Amer. Chem. Soc.*, 38, 221 (1916).

³ Baxter and Grover, *J. Amer. Chem. Soc.*, 37, 5 (1915).

⁴ Forbes, *J. Amer. Chem. Soc.*, 33, 1937 (1911).

⁵ Richards and Wadsworth, *loc. cit.*, p. 224.

NATIONAL RESEARCH COUNCIL
PRELIMINARY REPORT OF THE ORGANIZING COMMITTEE TO THE
PRESIDENT OF THE ACADEMY

By George E. Hale, Chairman

On April 19, 1916, at the closing session of the annual meeting, the Academy voted unanimously to offer its services to the President of the United States in the interest of national preparedness. The Council of the Academy was authorized to execute the work in the event of the President's acceptance.

On April 26 the President of the Academy, accompanied by Messrs. Conklin, Hale, Walcott, and Woodward, was received at the White House by the President of the United States. In presenting the resolution adopted at the annual meeting, it was suggested that the Academy might advantageously organize the scientific resources of educational and research institutions in the interest of national security and welfare. The President accepted this offer, and requested the Academy to proceed at once to carry it into effect.

Immediately following this visit, the President of the Academy, in harmony with resolutions adopted by the Council on April 19, appointed the following Organizing Committee: Messrs. Edwin G. Conklin, Simon Flexner, Robert A. Millikan, Arthur A. Noyes, and George E. Hale (*Chairman*).

At a meeting of the Council of the Academy, held in New York on June 19, the Organizing Committee presented the following statement of work accomplished up to that date.

Much time was devoted during the first five weeks to the organization of committees to meet immediate needs, including those on Nitric Acid Supply (A. A. Noyes, Chairman), in co-operation with the American Chemical Society; Preventive Medicine (Simon Flexner, Chairman), in co-operation with the Committee of Physicians and Surgeons, and Synthetic Organic Chemistry (M. T. Bogert, Chairman), in co-operation with the American Chemical Society. Special attention was also given to arrangements for co-operation with the scientific Bureaus of the Government, the Committee of Physicians and Surgeons, the Naval Consulting Board, the national societies devoted to branches of science in which committees were immediately needed, the national engineering societies, the larger research foundations, certain universities and schools of technology, and the leading investigators in many fields of research, both on the industrial and the educational side. The hearty encouragement received from all of these men and institutions leaves no doubt that, as soon as a general request for co-operation is sent out, it will meet with universal acceptance.

During this preliminary period a more comprehensive plan of organization was developed, and finally embodied in the form indicated below. It was recognized from the outset that the activities of the committee should not be confined to the promotion of researches bearing directly upon military problems, but that true preparedness would best result from the encouragement of every form of investigation, whether for military and industrial ap-

plication, or for the advancement of knowledge without regard to its immediate practical bearing. The scheme of organization must be broad enough to secure the co-operation of all important agencies in accomplishing this result.

After considering a variety of plans the Organizing Committee presented to the Council of the Academy the following recommendations:

"That there be formed a National Research Council, whose purpose shall be to bring into co-operation existing governmental, educational, industrial, and other research organizations with the object of encouraging the investigation of natural phenomena, the increased use of scientific research in the development of American industries, the employment of scientific methods in strengthening the national defense, and such other applications of science as will promote the national security and welfare.

"That the Council be composed of leading American investigators and engineers, representing the Army, Navy, Smithsonian Institution, and various scientific Bureaus of the Government; educational institutions and research endowments; and the research divisions of industrial and manufacturing establishments.

"That, in order to secure a thoroughly representative body, the members of the Council be chosen in consultation with the presidents of the American Association for the Advancement of Science, the American Philosophical Society, the American Academy of Arts and Sciences, the American Association of University Professors, and the Association of American Universities; that representatives of industrial research be selected with the advice of the Presidents of the Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Society of Electrical Engineers, and the American Chemical Society, and that members of the Cabinet be asked to name the representatives of the various Departments of the Government.

"That Research Committees of two classes be appointed, as follows: (a) Central committees, representing various departments of science, comprised of leading authorities in each field, selected in consultation with the president of the corresponding national society. (b) Local committees in universities, colleges and other co-operating institutions engaged in scientific research."

The Organizing Committee also recommended the following plan of procedure, subject to such modifications as the National Research Council may deem desirable.

"(1) The preparation of a national inventory of equipment for research, of the men engaged in it, and of the lines of investigation pursued in co-operating Government Bureaus, educational institutions, research foundations, and industrial research laboratories; this inventory to be prepared in harmony with any general plan adopted by the proposed Government Council of National Defense.

"(2) The preparation of reports by special committees, suggesting important research problems and favorable opportunities for research in various departments of science.

"(3) The promotion of co-operation in research, with the object of securing increased efficiency; but with careful avoidance of any hampering control or interference with individual freedom and initiative.

"(4) Co-operation with educational institutions, by supporting their efforts to secure larger funds and more favorable conditions for the pursuit of research and for the training of students in the methods and spirit of investigation.

"(5) Co-operation with research foundations and other agencies desiring to secure a more effective use of funds available for investigation.

"(6) The encouragement in co-operating laboratories of researches designed to strengthen the national defense and to render the United States independent of foreign sources of supply liable to be affected by war."

The Council of the Academy voted to accept the proposals of the Organizing Committee, and instructed it to proceed with the formation of the National Research Council in accordance with the plan recommended by the committee.

In consultation with the presidents of the various societies already mentioned, most of the members of the Council have now been chosen.

The endorsement of the President of the United States and the authority to secure the appointment of government representatives, is conveyed in the following letter to the President of the Academy:

WASHINGTON, D. C., July 24, 1916.

DR. WILLIAM H. WELCH,

President of the National Academy of Sciences, Baltimore, Maryland.

MY DEAR DR. WELCH:

I want to tell you with what gratification I have received the preliminary report of the National Research Council, which was formed at my request under the National Academy of Sciences. The outline of work there set forth and the evidences of remarkable progress towards the accomplishment of the object of the Council are indeed gratifying. May I not take this occasion to say that the Departments of the Government are ready to co-operate in every way that may be required, and that the heads of the Departments most immediately concerned are now, at my request, actively engaged in considering the best methods of co-operation?

Representatives of Government Bureaus will be appointed as members of the Research Council as the Council desires.

Cordially and sincerely yours,

[Signed] WOODROW WILSON.

Under this authority, the appointment of representatives of the Army, Navy and various scientific Bureaus of the Government will now be arranged with the members of the Cabinet. It is expected that the first meeting of the Council will be held in September.

It has already been stated that cordial desire to co-operate has been encountered on every hand. Special reference may now be made to certain striking cases. The first of these illustrates how the Council, taking advan-

tage of the increased appreciation of the value of science and the spirit of national service which have resulted from the war, may obtain the co-operation of educational institutions and assist them in adding to their endowments for scientific research. Throop College of Technology, in Pasadena, California, is a small institution of high standards which gives special attention to research. President Scherer, hearing of the plans of the Research Council, offered the assistance and co-operation of the recently endowed Research Laboratory of Chemistry and secured at once an additional endowment of one hundred thousand dollars for scientific research. Under somewhat similar circumstances, a gift of \$500,000 has been made to the endowment of the Massachusetts Institute of Technology, with the expectation that much of the income will be used for research at that Institution.

Another illustration of friendly co-operation, of special importance because it assures the support of the National Engineering Societies, is afforded by the following resolution of the Engineering Foundation of New York, adopted at the annual meeting of the Foundation, on June 21, 1916:

"WHEREAS, the National Academy of Sciences of the United States of America has taken the initiative in bringing into co-operation existing governmental, educational, industrial, and other research organizations with the object of encouraging the investigation of natural phenomena, the application of scientific principles in American industries, the employment of science in the national defense, and such other objects as will promote the national welfare, and

"WHEREAS, these objects are among the objects for which The Engineering Foundation was created,

"Now, Therefore, be it Resolved, that The Engineering Foundation hereby registers its approval of the co-ordination and federation of the research agencies of the country undertaken by the National Academy of Sciences and expresses its willingness to join with and assist the National Academy in accomplishing the above federation."

The Foundation also offered to devote its entire income for the coming year (including a special gift of \$5000 for this purpose from its founder, Mr. Ambrose Swasey) toward the expenses of organization, and to provide a New York office for the Council in the Engineers Building.

The Presidents of the American Philosophical Society, of the American Association of University Professors, and of Yale University have already expressed their intention of proposing the adoption of similar resolutions by the institutions which they represent and of recommending the appointment of committees to co-operate with the National Research Council; and it is expected that other societies and educational institutions will take similar action.

Respectfully submitted by the Organizing Committee,

GEORGE E. HALE (Chairman),
EDWIN G. CONKLIN,
SIMON FLEXNER,
ROBERT A. MILLIKAN,
ARTHUR A. NOYES.

